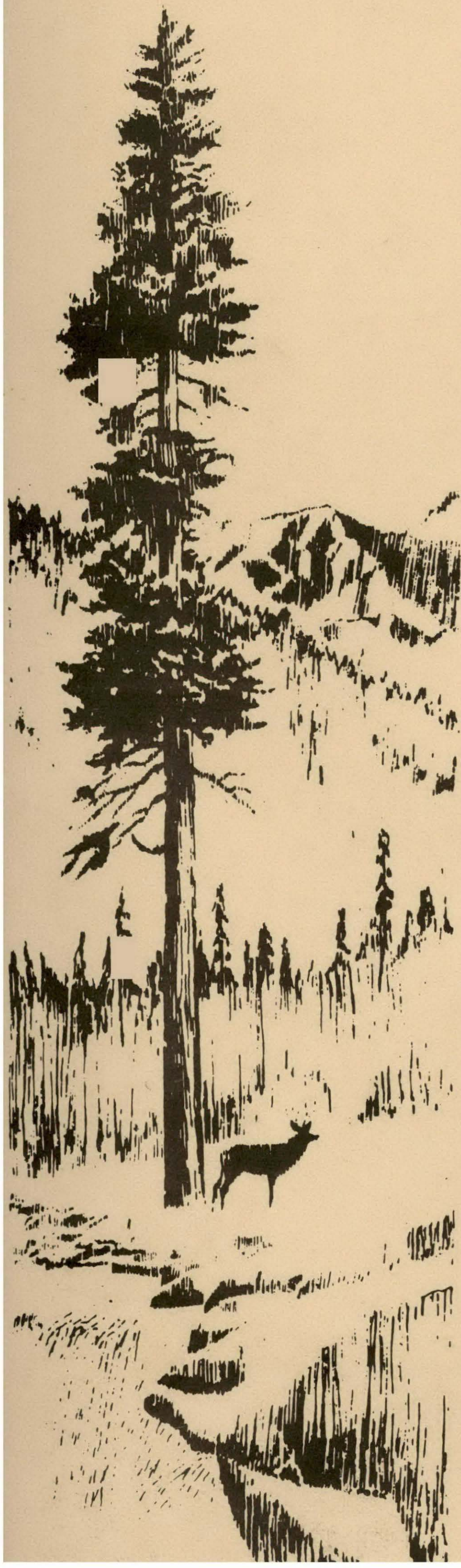

College of Forestry, Wildlife and Range Sciences

CANUSA Spruce Budworms Program-West

Final Report

by

Peter G. Mika

August 1984

Forest, Wildlife and Range Experiment Station

University of Idaho

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TITLE: Western Spruce Budworm Impact Assessment: Hazard Model Validation and Vulnerability Model Development

PRINCIPAL INVESTIGATOR: Peter G. Mika
College of Forestry, Wildlife and Range Sciences
University of Idaho
Moscow, ID 83843

ACTIVITY NO. 2.2.1

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Summary

Losses due to WBW-caused damage on the Okanogan and Wenatchee National Forests were re-analyzed using an individual tree approach to calculating growth impact. Based on the latter, average diameter growth loss associated with WBW defoliation in the period 1971 to 1980 was 0.25 inches, 0.43 inches and 0.36 inches on Douglas-fir, grand fir and subalpine fir, respectively. These amount to reductions of 19.8, 34.6 and 30.8 percent for the three species.

Loss rates were calculated on a stand-by-stand basis. Rates included: (1) top-killing in trees per acre and basal area per acre; (2) mortality in trees, basal area and volume per acre; and (3) growth loss in basal area and volume per acre. 11.6 trees per acre suffered top-kill, this corresponding to 8.6 percent of the host trees. Mortality attributed to budworm damage averaged 4.0 square feet of basal area and 107.4 cubic feet of volume per acre, corresponding to a mortality rate of 3.3 percent for the ten-year period. Growth losses averaged 4.5 square feet of basal area and 146.6 cubic feet of volume per acre. These values correspond to reductions of 4.6 and 5.9 percent in live basal area and volume in 1980. Similar loss figures for total loss (growth plus mortality) were 8.1 square feet and 240.6 cubic feet corresponding to reductions of 7.5 and 8.8 percent from potential 1980 basal area and volume, respectively.

Vulnerability models relating the amount of impact to site and stand characteristics were developed. Simple regression relationships were developed for predicting growth and total losses. Growth and total loss were higher in stands close to 3700 feet in elevation, in stands with a large amount of host, particularly true fir, and in stands uniform in height. Models for mortality and topkill involved two parts: one model for the probability the event will occur and another model for the amount of impact. The chance of mortality

increases as the amount of host and the proportion of host in true fir increases. Magnitude of mortality follows a similar trend with heavier mortality rates on northerly aspects. Topkill models were more complex involving percent slope, aspect, site vigor, amount of host, amount of true fir and tree size.

Impact rates were compared to aerial survey ratings of budworm infestation level. The number of years of detectable budworm infestations showed significant positive correlation with all impact variables; strongest correlations were with growth loss and topkill rate. Impact rates were also positively correlated with predicted risk calculated from a model previously developed for the area around Twisp, Washington.

Introduction

The ability to predict changes in pest populations and damage levels is needed in any effective pest management system. This is particularly true in managing forest pests: we cannot afford to apply expensive control programs over large acreages nor do we have the resources to maintain detailed monitoring of pest populations over large land areas. Thus hazard rating systems that allow us to concentrate our management efforts on particular locations and/or times are of great value.

The pest management problem associated with the western budworm (Choristoneura occidentalis Freeman) is no exception. Consequently, considerable effort has been spent on developing empirically derived hazard or risk rating models for this insect, based both on aerial photography and ground survey data. Unfortunately, because of the empirical basis for these models we cannot be sure how good a job they will do when applied to conditions different than those sampled to develop the models. Conversely, if the models correctly describe hazard conditions in a test situation we can feel more confident that the relationships portrayed in the model will yield useful predictions under a variety of conditions. Thus, when presented with suitable data, it behooves us to test out the available models and assess their correctness; that is, given the opportunity we should attempt to validate these risk rating models.

Such a situation arose when Forest Pest Management of Region 6 conducted a WBW damage assessment survey in 1980 on the Okanogan and Wenatchee National Forests. Although the survey did not collect detailed information on budworm population levels or defoliation rates, it did gather a large amount of data on radial growth impacts associated with WBW damage along with sufficient data on stand and site characteristics to drive most of the available budworm risk rating models. This was one of the major goals of the present study:

to use the data from this survey as a validation test of existing WBW risk rating models. Obviously, such data could also be used to examine relationships between WBW-caused damage and stand characteristics; this was another major objective of this study.

However, before any such tests can be conducted, the data must first be summarized in a form yielding stand-specific impact rates. The intention of the original survey was to determine impacts "of individual tree injury on a stand-by-stand basis" (Harvey 1982). To accomplish this objective, data collected included annual radial increments for host and nonhost trees. The idea was to use this data to obtain individual stand radial growth impact by analysis of covariance on a stand-by-stand basis. Unfortunately, insufficient data for nonhost trees was collected to allow this; thus, covariance analysis was performed on two pooled samples of stands and any ability to develop stand-specific radial growth impacts was lost.

The first objective of the present study was to circumvent the above problem by adopting a different analysis strategy. If we assume that diameter growth will continue at a steady rate at least over short time periods in the absence of any major perturbations, we can use pre-defoliation growth rates to calculate post-defoliation growth rates expected to be found if WBW did not occur. This individual tree approach would preserve our ability to calculate stand-by-stand growth impacts and allow us to use this survey data for validating risk rating models and developing a WBW vulnerability model for the area.

The objectives discussed above can be summarized as follows:

(1) determine stand specific damage rates resulting from WBW feeding on the Okanogan and Wenatchee National Forests using the individual tree approach described above,

(2) compare the calculated impact values from (1) with impacts determined by other studies in the same area,

(3) develop a vulnerability model relating the impacts in (1) to site and stand characteristics, and

(4) compare the impact values from (1) with predicted risk rates obtained from existing risk models.

All of these objectives have been accomplished and are reported here.

Methods

Survey design and data collection procedures were described by Harvey (1982). In brief, stands were selected from three major strata: (1) nonoutbreak--stands in which less than three years of light defoliation occurred, (2) post-outbreak treated--stands that were sprayed for control of WBW, and (3) post-outbreak nontreated--stands with more than three years of light defoliation that were not treated. Within each stratum stands were selected from four substrata: (1) single-storied pure host, (2) multi-storied pure host, (3) single-storied mixed host/nonhost, and (4) multi-storied mixed host/nonhost. Pure host stands were those with 80 percent or more of total basal area in host species (Douglas-fir, true firs, Engelmann spruce and western larch) while in mixed stands, host species comprised a major component of the stand but less than 80 percent of the basal area based on Total Resource Inventory records. One hundred two stands were sampled.

Data was collected on variable radius plots established at a rate of one plot per five acres. For trees of diameter at breast height of five inches or more, the following information was recorded: species, DBH, crown class and crown ratio. Height and crown width were measured on a subsample. For host trees, incidence of top-kill, degree of defoliation

and causes of mortality were also recorded. For stands in strata 2 and 3 (77 stands) increment cores were collected from approximately 30 host and 3 nonhost trees in each stand and measured to determine annual growth from 1960 through 1980. In addition, stand attributes including elevation, slope, aspect and site productivity were determined. Aerial survey maps were used to determine the number of years a stand sustained moderate to heavy WBW defoliation.

Radial growth impact was calculated for each tree for which an increment core was collected. First, based on 1980 diameter and 1960 through 1980 radial increment measurements, cumulative diameters were calculated for 1960 through 1980. Cumulative diameters were used so that radial growth would be monotonically increasing function of time. Values for 1960 to 1970 were then used to obtain a standard least squares fit of the model: diameter $= b_0 + b_1 * \text{time} + b_2 * 1/\text{time}$ where time equals the number of years since 1959. This particular model form was chosen because of its simplicity and ability to adequately represent short term tree growth as shown by Olson (1980) and because solutions for its parameters were easy to obtain. The 1960 to 1970 cumulative diameters correspond to growth previous to any WBW defoliation. The resultant model was then used to calculate "expected" cumulative diameters for the period 1971 to 1980. Any difference in expected and actual diameter in 1980 for the host trees was considered to be impact from WBW-caused injury. Average impact values were then calculated for each host species in each stand.

Actual basal area and volume in 1980 were calculated for each variable radius plot tree. Volumes were calculated to a 5-inch top; the algorithm, provided by Tommy F. Gregg[1/], required tree diameter and height. The latter was estimated by fitting the model: $\ln(\text{height} - 4.5) = a + b * (1/(1+\text{diameter}))$.

[1/] Forestry Technician, USDA Forest Service, Region 6, State and Private Forestry, Forest Pest Management.

using all trees measured for height in the stand and then predicting the "actual" height in 1980 based on 1980 diameter. These values were summed over all trees in the stand to obtain actual stand basal areas and volumes.

Expected diameters were obtained by adding the average impact values to the actual diameter. Three expected volumes were calculated. One value was obtained using the 1980 expected diameter and the 1980 "actual" height as calculated previously. This would correspond to an assumption that WBW damage did not impact tree height growth. For the second volume estimate an adjustment was made for assumed height growth loss due to WBW damage based on work by Thomson and Van Sickle (1980). Here it was assumed that whenever sufficient WBW defoliation took place that it was visible during the annual aerial survey, the damage to the tree terminals would be sufficient to produce no height growth that year. Thus a second height-diameter curve was fit using 1980 heights and diameters adjusted back by the number of years of detected defoliation. This curve was then used to estimate expected 1980 height based on expected 1980 diameter. Again these values were summed to obtain expected basal areas and volumes for each stand. Volumes calculated using these first two calculated heights were reported previously (Mika and Twardus 1983).

A third volume was calculated using a height adjustment based on detailed tree ring measurements analyzed by Tom Nichols at the University of Washington (personal communication June, 1983). Nichols found that for host trees during the first six years of an active budworm outbreak, the reduction in relative height growth was the same as the reduction in relative basal area growth (actual height growth/expected height growth = actual basal area growth/expected basal area growth). Accordingly, an expected height was calculated by substituting the expected tree diameter into the height-diameter curve based on measured values.

These stand impact values, the goal of the first objective for this study, formed the major portion of the data base needed for accomplishing the other study objectives. Because of the importance of this data for the remainder of this study's objectives, an attempt was made to validate the figures using results from other studies. Due to the paucity of comparable data, comparison of these impact values were made only to the results of analysis conducted by Tom Nichols at the University of Washington. The latter consisted of information on basal area growth reduction based on tree ring data collected from five general areas on the Wenatchee and Okanogan National Forests (Scott and Nichols 1983). Stands from the present study for which growth reduction information was available (those in strata 2 and 3) were matched geographically to these five areas; 48 of the 77 available stands could be reasonably classed into one of the areas. Comparison was then made between average growth reduction rates for these 48 stands and the comparable figures from Nichols' work.

The various stand impact values were then used as dependent variables in regression models for stand vulnerability to WBW damage. Independent variables included various site and stand characteristics: elevation, slope, aspect, site vigor (mean height/age for site trees), tree density (trees per acre, basal area per acre, volume per acre), species composition (host and true fir trees per acre, basal area per acre and volume per acre) and tree size (mean and variance of diameter and height for host trees and all trees). Standard regression techniques were utilized in the analysis.

Logarithmic transformation of the dependent variables was necessary to produce normally distributed residuals in all cases. Consequently, some means of correcting for bias was necessary to obtain from the regression models proper estimates of impact in original units. Based on work

by Bradu and Mundlak (1970) an infinite series correction factor was used for this purpose:

Let Z = original dependent variable

$y = \ln(Z)$

x_i = the i^{th} independent variable

Then our regression model is

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_p X_p + \varepsilon = \underline{X}'\underline{\beta} + \varepsilon$$

where $\varepsilon \sim N(0, \sigma^2)$

We can then obtain an unbiased estimate for the expected value of Z for a particular value of $\underline{X}$ using the following:

$$E(\hat{Z}) = e^{\hat{y}}\, g_m \left[\frac{m+1}{2m}(\hat{\sigma}^2 - \hat{\sigma}^2_{\hat{y}})\right]$$

where $\hat{y} = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_p X_p = \underline{X}'\underline{b}$

m = degrees of freedom = $n - (p + 1)$

$\hat{\sigma}^2$ = mean squared error for the regression

$\hat{\sigma}^2_{\hat{y}} = \underline{X}'[(\underline{X}'\underline{X})^{-1}\hat{\sigma}^2]\underline{X} \equiv \underline{X}'\mathrm{Var}(b)\,\underline{X}$

and $g_m(t) = \sum_{i=0}^{\infty} \frac{m^i(m + 2i)}{m(m+2)\dots(m+2i)} \left(\frac{m}{m + 1}\right)^i \frac{t^i}{i!}$

Beauchamp and Olson (1973) report a second order approximation that appears to give good results and avoids needing to evaluate the infinite series:

$$E(Z) \doteq e^{\hat{y} + \frac{1}{2}\hat{\sigma}^2}\left\{1 - \frac{\hat{\sigma}^2(2\phi + \hat{\sigma}^2)}{4n} + \frac{(\hat{\sigma}^2)^2\,[(\hat{\sigma}^2)^2 + 2(16/3 + 2\phi)\hat{\sigma}^2 + 4\phi^2 + 16\phi]}{32n^2}\right\}$$

where $\phi = \hat{\sigma}^2_{\hat{y}}\left(\frac{n}{\hat{\sigma}^2}\right)$

Thus one still needs to evaluate $\hat{\sigma}^2_{\hat{y}}$, the variance associated with the particular $\underline{X}$.

Additional complications arose when developing vulnerability models for topkill and mortality. Examining the distribution of values showed a large number of zero values accompanied by a number of positive values that appeared to be log normally distributed. This describes the delta distribution discussed by Aitchison and Brown (1957):

$$Z \sim \Delta(\delta, \mu, \sigma)$$

where

$$P\{Z < 0\} = 0$$

$$P\{Z = 0\} = \delta$$

$$P\{Z \leq y\} = \delta + (1 - \delta)\, \Lambda\, (Z \mid \mu, \sigma^2)$$

and Λ is the log normal c.d.f. evaluated at y.

Following the same notation used previously, an unbiased estimate of the expected value of Z for a particular $\underline{X}$ would be:

$$\hat{Z} = (1 - \hat{\delta})\, e^{\hat{y}}\, g_m \left[\frac{m+1}{2m} (\hat{\sigma}^2 - \hat{\sigma}_{\hat{y}})\right]$$

where $m = n_2 - (p + 1)$

n_2 = number of non zero observations of Z

and δ = the actual probability that the event (topkill, mortality) will not occur.

Logistic regression was used to develop the models for estimating δ while standard regression techniques were used to build models for $y = \ln(Z)$.

Other analysis involved comparisons of impact rates with predicted values obtained from existing budworm risk rating models and with aerial survey budworm ratings. Due to the similarity in areas sampled and the availability of information needed to drive the risk rating models, comparisons were limited to models developed by Anderson (1981). All comparisons were based on measures of simple correlation and data plots.

Results

Calculation of Impact Rates

Results obtained from the individual tree growth models were previously reported (Mika and Twardus 1983). The average differences between actual diameters measured in the field in 1980 and expected diameters calculated using these growth models are shown in Table 1. Under the assumption that any difference between actual diameter and expected diameter should reflect the impact of budworm-caused tree injury, we would expect to see significant differences for host trees but not for non-host trees. Examination of Table 1 shows that this condition was met: non-host trees did not show any significant difference between actual and expected diameters. The pattern present among the host species with the true fir species showing more diameter loss than Douglas-fir is in agreement with numerous other observations on differences in defoliation rates and impact among the host species (Williams et al 1971, Carolin and Coulter 1975, Stoszek et al 1981, Fellin et al 1983).

This data on diameter growth reduction also provided a basis for comparison with impact analysis from the same general area conducted by Tom Nichols at the University of Washington (personal communication June 1983). Average basal area growth reduction were calculated for those stands from the present study located close to the areas identified by Scott and Nichols (1983); 48 of the 77 stands with growth reduction data fell within these areas. Both data sets reflect calculated reductions for the period 1971 to 1980. The comparison, shown in Table 2, indicates that the estimates of growth reduction on host trees from the present study were lower than those calculated by Nichols by an average of 18 percent. However, Nichols found that the non-host trees showed a substantial decline (16 percent) in that time period while the present study showed an increase in basal area growth of 13 percent

Table 1. Means of individual tree diameter growth from 1971 to 1980 and growth loss associated with WBW-caused tree injury.

Tree Species	Sample Size	Average Diameter Growth (inches)		Average Growth Loss	
		Actual	Predicted	Predicted-Actual	% of Predicted
Douglas-fir	1646	0.9285	1.1750	0.2465	19.81
Grand fir	189	0.7946	1.2212	0.4266	34.56
Subapline fir	22	0.7434	1.1073	0.3639	30.79
Nonhost	177	0.8336	0.8752	0.0416	-2.25

Table 2. Comparison of average growth reduction values for the period 1971 to 1980 between those calculated by Nichols [1/] and those calculated in this study.

Host tree by area [2/]	Percent reduction in total basal area (100 x (Predicted - Actual)/Predicted)	
	Nichols' study	This study
I	36	9
II	47	37
III	11	-1
IV	20	21
V	21	-4
Total	28	10
Nonhost Trees	16	-13

1/Personal communication from Tom Nichols, College of Forest Resources, University of Washington, Seattle, June 1983.

2/Roman numerals correspond to general groups of stands as identified by Scott and Nichols (1983).

for non-host trees. Thus if adjusted to reflect differences between host and non-host trees, the present study would show the greater growth reduction for the host trees.

The comparison in Table 2 is certainly not the ideal comparison of two measurements on the same set of trees. Thus one cannot expect a very close agreement in values. Still, calculated reductions were of the same magnitude and relative differences among the five areas seemed similar. Thus I feel that Nichols' data supports the validity of the growth reduction calculations made in this study.

Incidence of top-killing was calculated for each stand in terms of number of trees per acre and square feet of basal area per acre of those trees for each host species. Individual stand values can be found in Tables A and B in the appendix. A summary of these rates is seen in Table 3. The average rate over all stands and species was 11.6 trees per acre or 5.6 square feet per acre. These values correspond to 8.6 percent of host trees and 5.7 percent of host basal area, respectively. It should be noted that for all strata and species the percent of total basal area involved in top-killed trees was less than the percent of trees per acre, indicating that top-killing was occurring more often in the smaller diameter trees. It is also of interest that the true fir species suffered much higher relative rates of top-killing than Douglas-fir, again indicating a higher rate of impact for the true fir species.

Mortality rates for individual stands are present in Tables C through F in the appendix. Table 4 shows a summary of these rates broken down by strata and species. Douglas-fir, the most prevalent host species, experienced about 3.5 percent mortality during the outbreak period, while grand fir mortality was about 5 percent. Rates of subalpine fir mortality appear much lower, but values are based on very few samples. The overall average of 3.3 percent

Table 3. Rates of top-killing in trees per acre and square foot basal area per acre broken down by species and stratum. Percentage rates are the averages over all stands containing a particular species of the percentage of the total live trees or basal area in the species found to have top-kill.

			Average Top-Kill Rates			
			Absolute Rate per Acre		Percent of Total Involved	
Stratum	Species	N	Trees	Basal Area	Trees	Basal Area
1	DF	25	5.4	3.0	4.1	3.2
	GF	12	11.3	3.5	11.8	7.7
	SAF	5	3.7	0.8	21.7	20.8
	Total	25	11.5	4.8	5.9	3.9
2	DF	39	9.4	5.9	12.2	7.9
	GF	29	10.1	3.3	10.8	7.9
	SAF	6	12.1	6.7	35.8	34.6
	Total	39	18.8	9.4	13.2	9.4
3	DF	38	3.7	1.9	3.8	2.9
	GF	14	1.3	0.9	10.3	9.7
	SAF	1	0.0	0.0	0.0	0.0
	Total	38	4.2	2.2	4.2	3.1
Total	DF	102	6.3	3.7	7.1	4.9
	GF	55	8.1	2.7	10.9	8.3
	SAF	12	7.6	3.7	26.9	26.0
	Total	102	11.6	5.6	8.6	5.7

Table 4. Mortality rates in trees, square foot basal area, cubic foot volume and board foot volume per acre broken down by species and stratum. Percentage rates are the averages over all stands containing a particular species of the percentage of the total amount (live and dead) in that species found to be dead.

			Average Mortality Rates							
			Absolute Loss per Acre				Percent of Total Involved			
Stratum	Species	N	Trees	Basal Area	Cubic Feet	Board Feet	Trees	Basal Area	Cubic Feet	Board Feet
1	DF	25	5.3	4.1	125.7	649.3	3.3	2.8	2.7	2.8
	GF	12	4.2	1.9	47.8	212.2	7.0	6.6	6.6	7.2
	SAF	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	25	7.3	5.0	148.7	751.1	3.7	3.1	3.1	3.2
2	DF	39	5.4	3.1	78.9	332.2	6.2	5.1	4.9	4.4
	GF	29	3.5	1.3	27.3	99.7	3.0	3.4	4.0	5.2
	SAF	6	1.9	0.7	10.0	4.4	3.1	1.8	1.5	0.3
	Total	39	8.3	4.2	100.7	407.1	4.5	3.9	3.8	3.9
3	DF	38	2.6	2.2	66.4	297.3	1.7	2.2	2.4	2.7
	GF	14	4.4	2.3	56.3	182.5	7.1	5.8	5.3	3.1
	SAF	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	38	4.2	3.1	87.1	364.5	2.6	2.7	2.8	2.8
TOTAL	DF	102	4.3	3.0	85.7	396.9	3.8	3.5	3.4	3.4
	GF	55	3.9	1.7	39.2	145.3	4.9	4.7	4.9	5.1
	SAF	12	1.0	0.3	5.0	2.2	1.6	0.9	0.7	0.2
	Total	102	6.5	4.0	107.4	475.6	3.6	3.3	3.3	3.3

mortality for the entire outbreak period would correspond to an annual rate of 0.34 percent. Total volume loss from mortality on an annual basis was 10.7 cubic feet per acre.

Growth loss rates for individual stands are presented in the appendix. Table G contains basal area growth loss rates. Tables H, I and J show cubic foot growth loss rates each differing as to the manner in which expected tree height was calculated: in Table H zero height growth was assumed to occur in years when budworm defoliation was visible from the air, in Table I budworm-caused tree damage was assumed to result in no reduction in height growth, and in Table J the reduction in height growth was assumed to be proportional to the reduction in diameter growth. Similar information on board foot growth losses are presented in Tables K, L and M; again, the tables differ according to the assumptions used in calculating expected tree height. Finally growth, mortality and total losses from budworm damage for individual stands are shown in Table N; values are grouped by sub-stratum and stratum.

This data is summarized in Table 5 though 8. Square foot basal areas and cubic foot volumes for growth loss, mortality and total loss for stratum 2 are shown in Table 5, similar data for stratum 3 is shown in Table 6, and averages over the two strata are presented in Table 7. Information on stratum 1 is not inlcuded as no growth data was collected for the stands in that stratum. Table 8 presents the growth loss and total loss information as a percentage of the expected live and expected total basal areas and volumes.

Average growth loss was 4.5 square feet per acre of basal area for the 10 year period; this corresponds to a reduction of 4.6 percent in total basal area from levels expected without WBW damage. Comparisons among sub-stratum indicate a trend of more loss (both growth and mortality) in stands in the single-storied, pure host sub-stratum. A weak trend also appears when comparing pure host types versus mixed types: the latter tends to

Table 6. Basal area (sq. ft.) and volume (cu. ft.) losses per acre for stands in stratum 2.

				Growth Loss				Mortality		Total Loss			
Structure	Composition	Species	N	BA	Volume 1/	Volume 2/	Volume 3/	BA	Volume	BA	Volume 1/	Volume 2/	Volume 3/
Single-storied	Pure host	DF	10	2.9	114.1	89.7	100.0	6.3	148.1	9.2	262.2	237.8	248.1
		GF	8	3.9	141.4	114.6	127.1	3.5	64.1	7.4	205.5	178.7	191.2
		SAF	3	2.2	71.0	53.4	68.9	1.3	20.0	3.6	91.0	73.4	88.9
		Total	10	6.7	248.5	197.4	222.4	9.4	205.4	16.2	453.9	402.8	427.8
	Mixed	DF	9	3.6	124.5	102.7	114.2	1.7	51.9	5.3	176.4	154.6	166.2
		GF	5	0.7	23.5	18.1	21.6	0.8	19.5	1.5	43.0	37.6	41.1
		SAF	0	-	-	-	-	-	-	-	-	-	-
		Total	9	3.9	137.5	112.7	126.2	2.2	62.8	6.1	200.3	175.5	189.0
Multi-stored	Pure host	DF	10	3.6	164.3	106.8	125.4	2.0	55.8	5.6	220.1	162.6	181.3
		GF	9	3.6	125.1	102.0	112.0	0.4	12.5	4.0	137.6	114.5	124.5
		SAF	2	0.9	27.7	24.1	29.8	0.0	0.0	0.9	27.7	24.1	29.8
		Total	10	7.0	282.4	203.4	232.2	2.4	67.1	9.4	349.5	270.5	299.3
	Mixed	DF	10	3.0	98.7	81.4	91.4	2.1	57.0	5.1	155.7	138.4	148.4
		GF	7	1.8	60.8	48.8	57.0	0.4	9.8	2.2	70.5	58.6	66.7
		SAF	1	1.4	44.5	39.1	45.6	0.0	0.0	1.4	44.5	39.1	45.6
		Total	10	4.4	145.7	119.5	135.8	2.4	63.8	6.7	209.5	183.3	199.7
Average		DF	39	3.3	125.4	94.9	107.6	3.1	78.9	6.3	204.3	173.8	186.5
		GF	29	2.7	96.5	78.2	87.3	1.3	27.3	4.1	123.8	105.5	114.6
		SAF	6	1.6	52.1	41.3	52.0	0.7	10.0	2.3	62.2	51.3	62.0
		Total	39	5.6	205.2	159.4	180.5	4.2	100.7	9.7	305.9	260.2	281.3

1/Volume losses calculated assuming budworm damage resulted in zero height growth during years when defoliation was detected from the air.

2/Volume losses calculated assuming budworm damage had no impact on height growth.

3/Volume losses calculated assuming height growth reduction from budworm damage was proportional to diameter growth reduction.

Table 6. Basal area (sq. ft.) and volume (cu. ft.) losses per acre for stands in stratum 3.

				Growth Loss				Mortality		Total Loss			
Structure	Composition	Species	N	BA	Volume 1/	Volume 2/	Volume 3/	BA	Volume	BA	Volume 1/	Volume 2/	Volume 3/
Single-storied	Pure host	DF	10	4.0	150.2	129.1	147.2	4.3	134.3	8.3	284.5	263.3	281.5
		GF	8	2.0	69.7	59.4	67.5	1.0	29.9	3.0	99.6	89.3	97.5
		SAF	0	-	-	-	-	-	-	-	-	-	-
		Total	10	5.6	206.0	176.6	201.2	5.1	158.2	10.7	364.2	334.8	359.4
	Mixed	DF	10	2.3	65.3	62.4	65.3	0.5	15.4	2.8	80.7	77.8	80.7
		GF	3	1.4	50.0	43.0	47.4	8.0	183.0	9.4	233.0	226.0	230.3
		SAF	0	-	-	-	-	-	-	-	-	-	-
		Total	10	2.7	80.3	75.3	79.5	2.9	70.3	5.6	150.6	145.6	149.8
Multi-storied	Pure host	DF	5	1.2	40.7	36.1	39.0	1.0	28.1	2.2	68.8	64.2	67.1
		GF	3	0.7	21.3	18.3	20.0	0.0	0.0	0.7	21.3	18.3	20.0
		SAF	1	0.3	9.4	8.2	10.2	0.0	0.0	0.3	9.4	8.2	10.2
		Total	5	1.7	55.4	48.7	53.1	1.0	28.1	2.6	83.5	76.8	81.1
	Mixed	DF	13	2.7	97.0	78.2	90.2	2.4	68.0	5.1	165.0	146.2	158.2
		GF	0	-	-	-	-	-	-	-	-	-	-
		SAF	0	-	-	-	-	-	-	-	-	-	-
		Total	13	2.7	97.0	78.2	90.2	2.4	68.0	5.1	165.0	146.2	158.2
Average		DF	38	2.7	95.3	81.9	91.9	2.2	66.3	5.0	161.6	148.2	158.3
		GF	14	1.6	55.1	47.1	53.0	2.3	56.3	3.9	111.4	103.4	109.3
		SAF	1	0.3	9.4	8.2	10.2	0.0	0.0	0.3	9.4	8.2	10.2
		Total	38	3.3	115.8	99.5	111.7	3.1	87.1	6.4	202.9	186.6	198.8

1/Volume losses calculated assuming budworm damage resulted in zero height growth during years when defoliation was detected from the air.

2/Volume losses calculated assuming budworm damage had no impact on height growth.

3/Volume losses calculated assuming height growth reduction from budworm damage was proportional to diameter growth reduction.

Table 7. Basal area (sq. ft.) and volume (cu. ft.) losses per acre for all stands.

				Growth Loss				Mortality		Total Loss			
Structure	Composition	Species	N	BA	Volume 1/	Volume 2/	Volume 3/	BA	Volume	BA	Volume 1/	Volume 2/	Volume 3/
Single-storied	Pure host	DF	20	3.5	132.2	109.4	123.6	5.3	141.2	8.8	273.4	250.6	264.8
		GF	16	3.0	105.5	87.0	97.3	2.2	47.0	5.2	152.6	134.0	144.3
		SAF	3	2.2	71.0	53.4	68.9	1.3	20.0	3.6	91.0	73.4	88.9
		Total	20	6.2	227.3	187.0	211.8	7.3	181.8	13.5	409.1	368.8	393.6
	Mixed	DF	19	2.9	93.3	81.5	88.5	1.1	32.7	4.0	126.0	114.2	121.2
		GF	8	0.9	33.4	27.4	31.3	3.5	80.8	4.4	114.3	108.3	112.1
		SAF	0	-	-	-	-	-	-	-	-	-	-
		Total	19	3.3	107.4	93.0	101.6	2.6	66.7	5.9	174.1	159.8	168.4
Multi-storied	Pure host	DF	15	2.8	123.1	83.2	96.6	1.7	46.6	4.5	169.7	129.8	143.2
		GF	12	2.9	99.1	81.1	89.0	0.3	9.4	3.2	108.5	90.5	98.4
		SAF	3	0.7	21.6	18.8	23.2	0.0	0.0	0.7	21.6	18.8	23.2
		Total	15	5.2	206.7	151.8	172.5	1.9	54.1	7.2	260.8	205.9	226.6
	Mixed	DF	23	2.8	97.7	79.6	90.7	2.3	63.2	5.1	161.1	142.8	153.9
		GF	7	1.8	60.8	48.8	57.0	0.4	9.8	2.2	70.5	58.6	66.7
		SAF	1	1.4	44.5	39.1	45.6	0.0	0.0	1.4	44.5	59.1	45.6
		Total	23	3.4	118.2	96.2	110.0	2.4	66.2	5.8	184.4	162.4	176.2
Average		DF	77	3.0	110.5	88.5	99.9	2.7	72.7	5.7	183.2	161.2	172.6
		GF	43	2.4	83.0	68.1	76.1	1.6	36.7	4.0	119.8	104.8	112.9
		SAF	7	1.5	46.1	36.5	46.0	0.6	8.6	2.0	54.6	45.1	54.6
		Total	77	4.5	161.1	129.8	146.6	3.6	94.0	8.1	255.1	223.8	240.6

1/Volume losses calculated assuming budworm damage resulted in zero height growth during years when defoliation was detected from the air.

2/Volume losses calculated assuming budworm damage had no impact on height growth.

3/Volume losses calculated assuming height growth reduction from budworm damage was proportional to diameter growth reduction.

Table 8 . Growth and total losses expressed as a percent of the expected live and expected total (live and mortality), respectively, in the species of interest for all measured stands.

				Percent Growth Loss				Percent Total Loss			
Structure	Composition	Species	N	BA	Volume 1/	Volume 2/	Volume 3/	BA	Volume 1/	Volume 2/	Volume 3/
Single-storied	Pure host	DF	20	4.2	5.7	4.7	5.1	9.8	10.5	9.6	9.9
		GF	16	8.2	11.7	10.1	11.0	12.2	15.0	13.6	14.4
		SAF	3	7.3	11.4	9.0	11.1	10.4	13.8	11.5	13.5
		Total	20	5.4	7.4	6.2	6.9	10.2	11.6	10.5	11.2
	Mixed	DF	19	3.3	4.4	3.8	4.2	4.3	5.5	4.9	5.3
		GF	8	8.9	15.1	13.1	14.0	18.6	24.8	23.2	23.9
		SAF	0	-	-	-	-	-	-	-	-
		Total	19	3.5	4.8	4.1	4.5	5.6	6.8	6.2	6.6
Multi-storied	Pure host	DF	15	3.5	4.8	3.7	4.1	6.7	8.3	7.3	7.7
		GF	12	8.0	12.2	10.0	10.7	8.5	12.7	10.6	11.3
		SAF	3	7.7	13.0	11.5	13.8	7.7	13.0	11.5	13.8
		Total	15	5.0	7.0	5.6	6.3	7.0	9.1	7.8	8.5
	Mixed	DF	23	4.2	5.7	4.7	5.2	7.7	9.3	8.4	8.9
		GF	7	6.1	8.7	7.2	8.0	6.9	9.4	7.9	8.6
		SAF	1	7.9	14.0	12.5	14.3	7.9	14.0	12.5	14.3
		Total	23	4.4	6.2	5.2	5.8	7.1	9.1	8.0	8.7
Average		DF	77	3.8	5.2	4.3	4.7	7.2	8.5	7.6	8.0
		GF	43	8.0	12.0	10.1	11.0	11.5	15.3	13.6	14.4
		SAF	7	7.5	12.4	10.6	12.7	8.9	13.4	11.6	13.7
		Total	77	4.6	6.3	5.3	5.9	7.5	9.2	8.2	8.8

1/Volume losses calculated assuming budworm damage resulted in zero height growth during years when defoliation was detected from the air.

2/Volume losses calculated assuming budworm damage had no impact on height growth.

3/Volume losses calculated assuming height growth reduction from budworm damage was proportional to diameter growth reduction.

show lower growth losses.

Volume growth losses calculated assuming a reduction in height proportional to a diameter reduction yielded loss values intermediate to the other two calculations. As these values both represented a compromise estimate and were based on assumptions found to hold true in the immediate area (Nichols, personal communication), these values were used in subsequent analysis. Under these assumptions 147 cubic feet of growth and 94 cubic feet of mortality were lost per acre from 1971 to 1980 for a combined loss of 241 cubic feet per acre; this latter corresponds to an 8.8 percent reduction in volume from expected levels with no WBW damage.

Development of Vulnerability Models

A. Growth loss and total loss models

Stands in strata 2 and 3--those in which individual tree growth information was collected--provided the data for development of the growth loss vulnerability models. The basic intention was to provide models capable of predicting the level of damage that a WBW outbreak was likely to cause in a stand based on the physical attributes of the stand. The list of potential predictor variables along with descriptive statistics on the values of those variables are shown in Table 9. Site characteristics included elevation, percent slope, aspect and site vigor (50 x height/age for site trees) while stand attributes included total density, host density, true fir density, tree size and variation in tree size. These variables along with various transformations formed the complete set of independent variables used in building the regression models.

Two sets of dependent variables were calculated: one set represented the impact of reduced tree growth rates while the other included both growth reduction and mortality losses. The growth loss calculations

Table 9. Descriptive statistics for site and stand characteristics used as candidate predictor variables in growth loss and total loss vulnerability models.

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
ELEV	ELEVATION (FEET)	77	3331.03896104	862.16615876	1600.00000000	5400.00000000
ASPECT	ASPECT (DEGREES)	77	205.71428571	117.80535431	45.00000000	360.00000000
SLOPE	PERCENT SLOPE	77	38.76623377	17.88405354	10.00000000	90.00000000
SITE	SITE VIGOR (HEIGHT/AGE FOR SITE TREES)	77	54.03116883	13.77283042	18.30000000	85.50000000
DENSE1	TOTAL TREES/ACRE	77	203.60389610	114.16003937	46.80000000	738.20000000
DENSE2	TOTAL BASAL AREA/ACRE (SQ.FT)	77	123.36623377	48.93563359	33.30000000	262.20000000
DENSE3	TOTAL VOLUME/ACRE (CU.FT)	77	3177.25194805	1435.04309165	539.70000000	7808.30000000
HOST1	PROPORTION OF TOTAL TREES IN HOST	77	0.77040260	0.17291527	0.34100000	0.98800000
HOST2	PROPORTION OF TOTAL BASAL AREA IN HOST	77	0.74940260	0.16181522	0.34800000	0.97000000
HOST3	PROPORTION OF TOTAL VOLUME IN HOST	77	0.74079221	0.16710036	0.34300000	0.96800000
HOST4	HOST TREES/ACRE	77	153.08383377	87.14115369	27.47160000	564.65550000
HOST5	HOST BASAL AREA/ACRE (SQ.FT)	77	92.54051039	42.20562467	25.97400000	227.91200000
HOST6	HOST VOLUME/ACRE (CU.FT)	77	2383.20544675	1278.46853167	451.72890000	6776.62200000
COMP1	TRUE FIR TPA/HOST TPA	77	0.21859740	0.28474722	0.00000000	0.86900000
COMP2	TRUE FIR BA/HOST VOLUME	77	0.18167532	0.24351086	0.00000000	0.77400000
COMP3	TRUE FIR VOLUME/HOST TPA	77	0.16601299	0.22832349	0.00000000	0.78700000
COMP4	TRUE FIR TREES/ACRE	77	34.89397791	49.91347199	0.00000000	215.20093980
COMP5	TRUE FIR BASAL AREA/ACRE (SQ.FT)	77	16.64109464	22.31644549	0.00000000	84.09840000
COMP6	TRUE FIR VOLUME/ACRE (CU.FT)	77	380.82813519	515.90852856	0.00000000	2048.89327143
MEAN_HD	MEAN DIAMETER--HOST TREES	77	10.11805195	2.09826936	7.31000000	16.57000000
MEAN_HH	MEAN HEIGHT--HOST TREES	77	60.84974026	11.32142159	39.39000000	99.01000000
MEAN_SD	MEAN DIAMETER--STAND TREES	77	10.13350649	2.04151438	7.40000000	16.59000000
MEAN_SH	MEAN HEIGHT--STAND TREES	77	60.76675325	10.97787445	37.59000000	87.72000000
VAR_HD	VARIANCE IN DIAMETER--HOST TREES	77	18.34610390	9.55351343	3.34000000	48.48000000
VAR_HH	VARIANCE IN HEIGHT--HOST TREES	77	293.12350649	196.95046979	14.51000000	1126.29000000
VAR_SD	VARIANCE IN DIAMETER--STAND TREES	77	20.06961039	10.74651442	4.62000000	60.36000000
VAR_SH	VARIANCE IN HEIGHT--STAND TREES	77	307.83610390	200.30880383	16.25000000	1286.73000000

Table 10. Descriptive statistics for growth loss and total loss data.

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
GL1	GROWTH LOSS IN BASAL AREA/ACRE	77	4.49090909	3.25188940	0	13.80000000
GL2	PROPORTION OF EXPECTED BASAL AREA LOST	77	0.04619481	0.02505680	0	0.11700000
GL3	GROWTH LOSS IN VOLUME/ACRE	77	147.34675325	117.92898129	0	539.90000000
GL4	PROPORTION OF EXPECTED VOLUME LOST	77	0.05967532	0.03646463	0	0.18600000
TL1	TOTAL LOSS IN BASAL AREA/ACRE	77	8.11558442	8.20415596	0	41.40000000
TL2	PROPORTION OF EXPECTED BASAL AREA LOST	77	0.07584416	0.05350063	0	0.24900000
TL3	TOTAL LOSS IN VOLUME/ACRE	77	241.34285714	245.37599428	0	1439.30000000
TL4	PROPORTION OF EXPECTED VOLUME LOST	77	0.08853247	0.05926071	0	0.27700000

were based on information on amount of reduction from levels expected to occur during the period 1971 to 1980. Total loss values were calculated by summing growth losses and mortality. Losses were calculated in terms of both basal area and cubic foot volume per acre. Measures of relative loss were also determined by calculating the ratio of absolute loss to the total level expected in 1980 assuming no WBW damage. These various indices of damage can be represented by the following notation:

Let A = actual amount of host growing stock present in 1980 (basal area or volume per acre)

E = amount of host growing stock expected to be present in 1980 assuming no WBW damage

M = actual amount of host mortality from 1971 to 1980

Then Growth Loss = E - A

Total Loss = Growth Loss + M

Relative Growth Loss = Growth Loss/E

Relative Total Loss = Total Loss/(E + M)

The basic statistics for these loss indices are displayed in Table 10; means correspond to values previously reported in Tables 7 and 8.

Distributions of values for the impact indices were examined for violations of normality assumptions. The upper histogram in figure 1 shows the distribution of basal area growth loss data to be strongly skewed to the right and non-normal. The lower indicates that a natural log transformation was fairly successful in normalizing the data. This trend was confirmed by a Kolmogorov-Smirnov test for normality. The original data had a maximum difference of 0.0985 while the transformed data had a difference of 0.06694; probabilities of getting those or larger differences under the assumption of normality were 0.064 and >0.15, respectively. The other growth loss indices (volume loss and relative growth loss) showed similar distributions; thus natural log

DISTRIBUTION OF GROWTH LOSS DATA

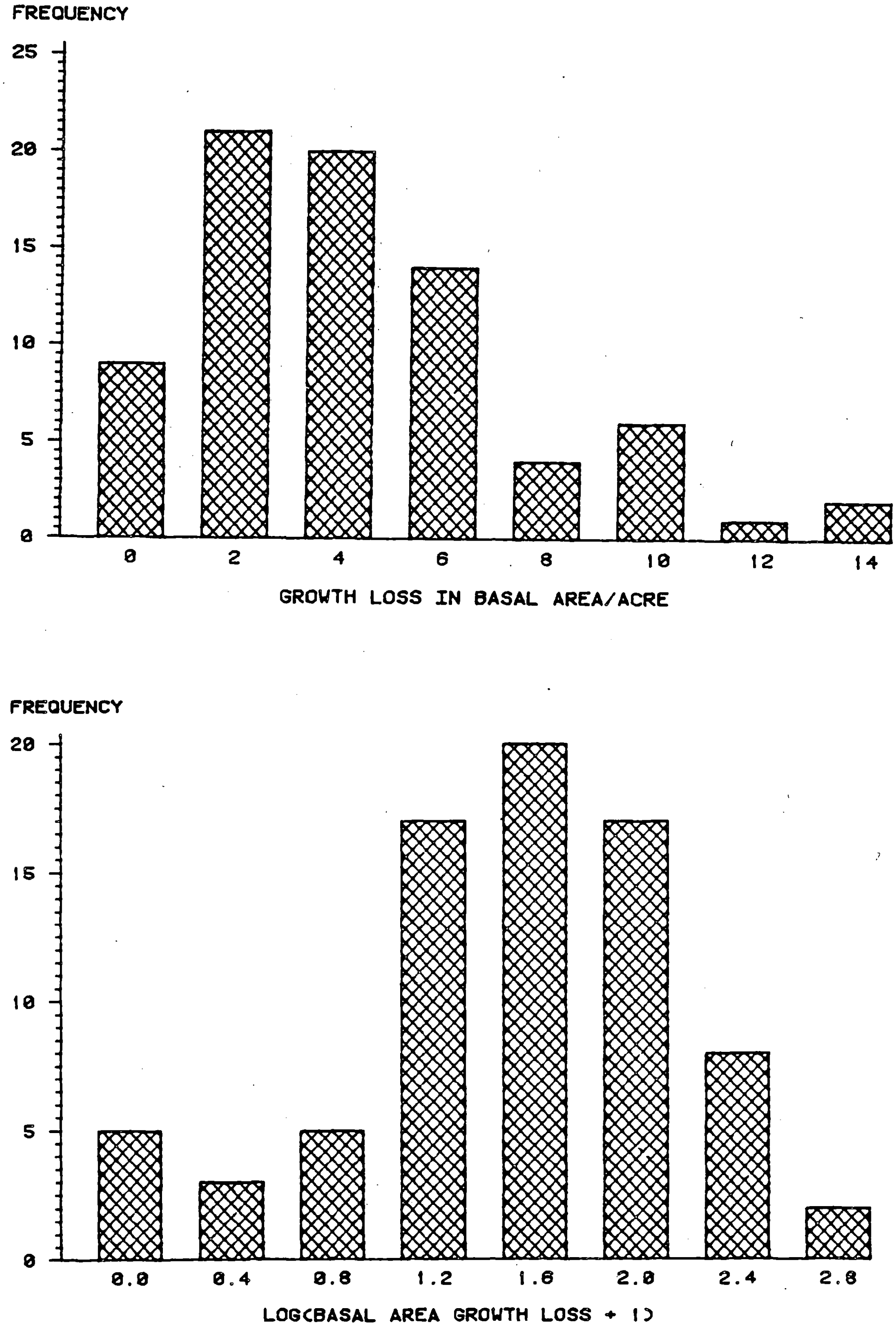


Figure 1. Histograms of data values (n=77) for growth loss in basal area per acre. The upper figure shows the distribution of the original data while the lower figure shows the distribution following a natural log transformation.

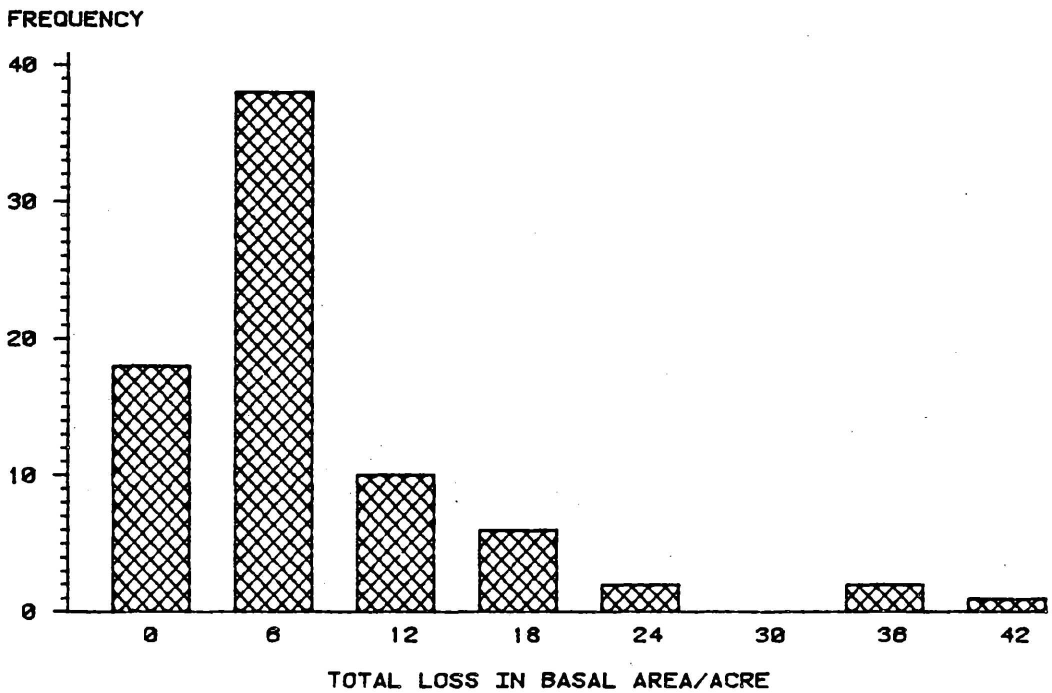
transformed values were used for all growth loss dependent variables in the regression analysis.

As would be expected, total loss data followed the same trend. Figure 2, showing the histograms for total loss in basal area per acre, again indicates that the original data is strongly skewed while the log transformed data appears fairly normal in distribution. Kolmosgorov-Smirnov normality test results were D = 0.1843 with probability <0.01 for the original data and D = 0.0684 with probability >0.15 for the transformed data. As with the growth loss data, all other indices showed similar trends and log transformed loss variables were used for all regression analysis.

Regression models and statistics for the growth loss indices are shown in Tables 11 through 14 while results for total loss indices are presented in Tables 15 through 18. All models were obtained through backwards elimination of non-significant independent variables. Independents in the final models are significant at a 5 percent level. Estimates of loss in logarithmic units can be obtained by substituting particular values of the independent variables into the regression equations [$\hat{y} = x'b$].

In addition to the estimates for the model parameters and basic fit statistics, each of the tables contains the estimated covariance matrix for the parameter estimates [$V(b) = (X'X)^{-1}\hat{\sigma}^2$]. This information is needed to obtain unbiased estimates of expected loss in original units for particular values of the independent variables. Further details on this subject were presented earlier in the methods section. The bottom section of each table, titled "comparison of estimators," shows the amount of bias introduced by use of different estimators of loss in original units. Estimates calculated correspond to the minimum, mean and maximum expected loss for the range of values of the inde-

DISTRIBUTION OF TOTAL LOSS DATA



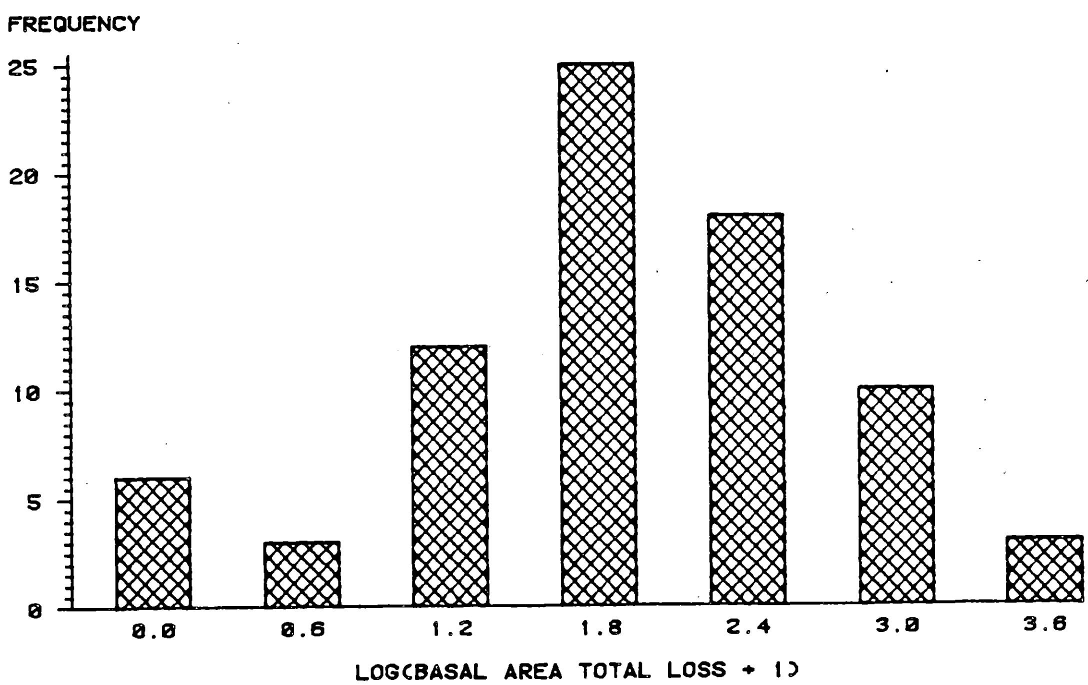


Figure 2. Histograms of data values (n=77) for total loss in basal area per acre. The upper figure shows the distribution of the original data while the lower figure shows the distribution after a natural log transformation.

pendent variables in this data set. The third column headed "$e^{\hat{y}}g_m$" gives the unbiased estimate. The first column gives an estimate obtained by taking the expected log value and applying the inverse transformation; this consistently underestimates the true value. The middle column shows the estimate obtained by substituting sample estimates $\hat{y}$ and $\hat{\sigma}^2$ for population parameters μ and σ^2 in the formula for the expected value of a log normal random variable [$E(z) = e^{\mu + \frac{1}{2}\sigma^2}$ where $\ln(z) \sim N(\mu,\sigma^2)$ see Aitchison and Brown 1957, section 2.3]. Estimates obtained by this latter method overestimate the true value but are closer to the unbiased estimates than those obtained with the first estimation technique. This subject will be discussed further later in this section.

The effect of elevation was expressed as the absolute deviation from 3,700 feet in all models predicting growth and total loss. Choice of 3,700 feet as a critical elevation was based on work by Anderson (1981), who found that WBW defoliation reached a peak at that elevation on the Okanogan National Forest. Anderson's data covered a range in elevation from 3,000 to 6,800 feet while stands sampled in this study ranged in elevation from 1,600 to 5,400 feet. Quadratic and cubic models of elevation were fit to determine the elevation at which maximum damage occurred in this study. Depending on the exact model formulation, maximum impact occurred somewhere between 3,500 and 4,100 feet. Thus 3,700 feet was a reasonable representative value for the elevation of maximum WBW impact in this study as well. The elevational effect was a significant predictor in all growth and total loss models.

Regression analysis for basal area per acre of growth loss resulted in two models shown in Tables 11a and 11b. Independent variables are the same in both models with exception of the measure of variation in tree size. The first model (Table 11a) uses the variation in tree

Table 11a. Regression model for growth loss in basal area per acre

Model: $\ln(\text{basal area/acre} + 1) = 9.7258 \times 10^{-1}$
$-1.7831 \times 10^{-4} \times |\text{elevation} - 3700|$ (feet)
$+3.0690 \times 10^{-4} \times$ host volume/acre (cubic feet)
$+4.5192 \times 10^{-3} \times$ true fir trees/acre
$-7.1975 \times 10^{-4} \times$ variance (stand height) (square feet)

$R^2 \doteq 0.5604$ $\hat{\sigma}^2 = 0.2027$

Covariance matrix for parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	2.0946×10^{-2}	-6.4683×10^{-6}	-3.1647×10^{-6}	-4.3386×10^{-5}	-1.4919×10^{-5}
b_1		8.0997×10^{-9}	-1.8606×10^{-10}	2.5666×10^{-8}	5.6810×10^{-10}
b_2			1.7247×10^{-9}	-5.7055×10^{-9}	-1.9892×10^{-9}
b_3				1.1710×10^{-6}	-7.7613×10^{-9}
b_4					6.3414×10^{-8}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}_{gm}$
minimum (1, 2100, 452, 0, 1287)	-0.173	-0.084	-0.126
mean (1, 721, 2383, 35, 308)	3.534	4.017	4.010
maximum (1, 0, 6777, 215, 16)	54.320	60.221	57.958

Table 11b. Regression model for growth loss in basal area per acre

Model: ln (basal area/acre + 1) = 1.0581
$-1.9708 \times 10^{-4} \times |\text{elevation} - 3700|$ (feet)
$+3.1336 \times 10^{-4} \times$ host volume/acre (cubic feet)
$+3.6601 \times 10^{-3} \times$ true fir trees/acre
$-1.3898 \times 10^{-2} \times$ variance (stand diameter) (square inches)

$R^2 = 0.5561$ $\hat{\sigma}^2 = 0.2047$

Covariance matrix for parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	2.6396×10^{-2}	-7.2668×10^{-6}	-2.6669×10^{-6}	-7.2248×10^{-5}	-4.7934×10^{-4}
b_1		8.2603×10^{-9}	-2.6903×10^{-10}	2.8621×10^{-8}	4.7446×10^{-8}
b_2			1.7928×10^{-9}	-9.0378×10^{-9}	-5.4624×10^{-8}
b_3				1.2621×10^{-6}	1.4504×10^{-6}
b_4					2.6144×10^{-5}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}gm$
minimum (1, 2100, 452, 0, 60)	-0.052	0.050	0.011
mean (1, 721, 2383, 35, 20)	3.534	4.022	4.015
maximum (1, 0, 6777, 215, 4)	48.651	54.002	52.129

heights while the second model (Table 11b) uses variation in tree diameters; data fit is nearly identical. This pattern of similar fit with both variation in height and diameter was true for all models of growth loss; generally, variation in height produced a slightly better fit.

Examination of model coefficients indicated that the amount of basal area growth loss was greater in stands with a higher density of host (in volume per acre) and larger true fir component (in trees per acre), in stands of more uniform size and in stands close to 3,700 feet in elevation. These same relationships were found in the models for volume growth loss (Tables 12a and 12b). In the latter models the influence of true fir composition is expressed as the proportion of host trees per acre in true fir rather than the absolute number of true fir trees per acre.

Relative growth loss models for basal area loss are shown in Tables 13a and 13b while relative volume loss models are displayed in Tables 14a and 14b. The models show behavior similar to the absolute loss models: loss increases as the true fir component increases, as the stand becomes more uniform in size and as the location nears 3,700 feet. The true fir composition is expressed in basal area per acre for these models. The major difference between the relative and absolute loss models is the absence of any expression of total host composition in the former.

The latter result indicates that the rate of damage per unit of host does not vary as the amount of host in the stand changes. The inclusion of a host composition effect in the absolute growth loss models serves only to account for the amount of host in the stand over which some average damage rate applies. This runs counter to results found in other studies where increases in percentage of host were

Table 12a. Regression model for growth loss in volume per acre

Model: $\ln(\text{volume/acre} + 1) =$ 3.6244

$-4.8189 \times 10^{-4} \times |\text{elevation} - 3700|$ (feet)

$+5.4387 \times 10^{-4} \times$ host volume/acre (cubic feet)

$+1.4373 \times \dfrac{\text{true fir trees/acre}}{\text{host trees/acre}}$

$-1.3623 \times 10^{-2} \times$ variance (stand height) (square feet)

$R^2 = 0.3583$ $\hat{\sigma}^2 = 1.4057$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	1.4838×10^{-1}	-4.2877×10^{-5}	-2.3655×10^{-5}	-5.8171×10^{-2}	-9.7807×10^{-5}
b_1		5.3758×10^{-8}	-3.4394×10^{-10}	1.8814×10^{-5}	2.6476×10^{-9}
b_2			1.1771×10^{-8}	9.9688×10^{-7}	-1.4187×10^{-8}
b_3				2.3702×10^{-1}	-3.1133×10^{-5}
b_4					4.4346×10^{-7}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}_{gm}$
minimum (1, 2100, 452, 0, 1287)	2.020	5.098	3.363
mean (1, 721, 2383, 0.22, 308)	86.169	175.034	172.330
maximum (1, 0, 6777, 0.87, 16)	5098.320	10296.900	8193.530

Table 12b. Regression model for growth loss in volume per acre

Model: $\ln$ (volume/acre + 1) = 3.6830

-4.9651×10^{-4} x |elevation - 3700| (feet)

$+5.3619 \times 10^{-4}$ x host volume/acre (cubic feet)

$+1.2065$ x $\frac{\text{true fir trees/acre}}{\text{host trees/acre}}$

-1.9864×10^{-2} x variance (stand diameter) (square inches)

$R^2 = 0.3413 \qquad \hat{\sigma}^2 = 1.4431$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	1.3062×10^{-1}	-3.2648×10^{-5}	-1.5014×10^{-5}	-6.1483×10^{-2}	-2.2355×10^{-3}
b_1		3.8395×10^{-8}	-4.4041×10^{-10}	1.4481×10^{-5}	1.4164×10^{-7}
b_2			8.4551×10^{-9}	-1.5205×10^{-6}	-2.2351×10^{-7}
b_3				1.7279×10^{-1}	8.4168×10^{-4}
b_4					1.2367×10^{-4}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}{}_{gm}$
minimum (1, 2100, 452, 0, 60)	4.38	10.08	7.55
mean (1, 721, 2383, 0.22, 20)	86.17	178.36	175.50
maximum (1, 0, 6777, 0.87, 5)	3916.44	8059.41	6487.68

Table 13a. Regression model for growth loss as a proportion of expected basal area per acre

Model: $\ln$ (proportion basal area/acre + 1) = 5.5671×10^{-2}
$-1.2345 \times 10^{-5} \times |\text{elevation} - 3700|$ (feet)
$+3.9904 \times 10^{-4} \times$ true fir basal area/acre (square feet)
$-2.7712 \times 10^{-5} \times$ variance (stand height) (square feet)

$R^2 = 0.3172$ $\qquad \hat{\sigma}^2 = 0.0004057$

Covariance matrix for parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	2.9355×10^{-5}	-1.2987×10^{-8}	-2.1557×10^{-7}	-3.6162×10^{-8}
b_1		1.5789×10^{-11}	8.9626×10^{-11}	3.5628×10^{-13}
b_2			1.1356×10^{-8}	-1.2358×10^{-10}
b_3				1.2332×10^{-10}

Comparison of estimators:

	χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}{}_{gm}$
minimum	(1, 2100, 0, 1287)	-0.0059	-0.0057	-0.0058
mean	(1, 721, 17, 308)	0.0459	0.0461	0.0461
maximum	(1, 0, 84, 16)	0.0928	0.0930	0.0930

Table 13b. Regression model for growth loss as a proportion of expected basal area per acre

Model: $\ln$ (proportion basal area/acre + 1) = 5.8986×10^{-2}
$-1.2905 \times 10^{-5} \times |\text{elevation} - 3700|$ (feet)
$+3.2664 \times 10^{-4} \times$ true fir basal area/acre (square feet)
$-5.1012 \times 10^{-4} \times$ variance (stand diameter) (square inches)

$R^2 = 0.3099$ $\hat{\sigma}^2 = 0.0004101$

Covariance matrix for parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	4.3245×10^{-5}	-1.4379×10^{-8}	-3.4927×10^{-7}	-1.0831×10^{-6}
b_1		1.6032×10^{-11}	9.6245×10^{-11}	6.0560×10^{-11}
b_2			1.1722×10^{-8}	4.2248×10^{-9}
b_3				4.8287×10^{-8}

Comparison of estimators:

X'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}{}_{gm}$
minimum (1, 2100, 0, 60)	0.0011	0.0013	0.0012
mean (1, 721, 17, 20)	0.0459	0.0461	0.0461
maximum (1, 0, 84, 5)	0.0877	0.0879	0.0879

Table 14a. Regression model for growth loss as a proportion of expected volume per acre

Model: $\ln(\text{proportion volume/acre} + 1) = 7.7197 \times 10^{-2}$
$-2.0108 \times 10^{-5} \times |\text{elevation} - 3700|$ (feet)
$+4.9242 \times 10^{-4} \times$ true fir basal area/acre (square feet)
$-4.3865 \times 10^{-5} \times$ variance (stand height) (square feet)

$R^2 = 0.3242 \qquad \hat{\sigma}^2 = 0.0008154$

Covariance matrix for parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	5.8995×10^{-5}	-2.6101×10^{-8}	-4.3324×10^{-7}	-7.2676×10^{-8}
b_1		3.1731×10^{-11}	1.8012×10^{-10}	7.1602×10^{-13}
b_2			2.2823×10^{-8}	-2.4837×10^{-10}
b_3				2.4784×10^{-10}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}_{gm}}$
minimum (1, 2100, 0, 1287)	-0.0212	-0.0208	-0.0210
mean (1, 721, 17, 308)	0.0591	0.0595	0.0595
maximum (1, 0, 84, 16)	0.1251	0.1255	0.1255

Table 14b. Regression model for growth loss as a proportion of expected volume per acre

Model: ln (proportion volume/acre + 1) = 8.3952×10^{-2}
-2.1079×10^{-5} x |elevation - 3700| (feet)
$+3.7193 \times 10^{-4}$ x true fir basal area/acre (square feet)
-8.7463×10^{-4} x variance (stand diameter) (square inches)

$R^2 = 0.3261$ $\hat{\sigma}^2 = 0.0008131$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	8.5750×10^{-5}	-2.8513×10^{-8}	-6.9257×10^{-7}	-2.1477×10^{-6}
b_1		3.1791×10^{-11}	1.9085×10^{-10}	1.2009×10^{-10}
b_2			2.3244×10^{-8}	8.3775×10^{-9}
b_3				9.5749×10^{-8}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}_{gm}}$
minimum (1, 2100, 0, 60)	-0.0130	-0.0126	-0.0127
mean (1, 721, 17, 20)	0.0591	0.0595	0.0595
maximum (1, 0, 84, 5)	0.1176	0.1180	0.1180

accompanied by increased defoliation per host tree (Fauss and Pierce 1969, Stoszek and Mika 1983) and increased vulnerability (Carlson et. al. 1983). It should be noted that only stands dominated by host were sampled in this study. Over 90 percent of the stand had at least half their basal area in host species. Thus the lack of a detectable relationship may reflect the absense in the study of stands with small percentages of host. The trend of decreasing loss as the variation in stand height or diameter increased is common to all growth loss models. Based on partial residual plots, it appears that this relationship primarily reflects consistent low loss values in stands with high variation in tree size. The levels of growth loss sustained by stands with more uniform structure covers a wide range of values. This result seems to contradict the commonly held idea that multistoried stands are more vulnerable to WBW than single-storied stands (Carlson et. al. 1983). However, a similar trend of decreasing WBW defoliation with increasing variation in age was found by Stoszek and Mika (1983) for an outbreak on the Clearwater National Forest.

The positive relationship between growth loss and amount of true fir in the stand is common to all growth loss models. As discussed earlier for individual trees, the greater vulnerability of the true firs as compared to Douglas-fir or Engelmann spruce is generally recognized throughout the West.

Total loss (growth loss + mortality) models are shown in Tables 15 (basal area loss), 16 (volume loss), 17 (relative basal area loss) and 18 (relative volume loss). As growth loss generally accounted for over half of total loss (see Table N in the appendix for further details) relationships found significant for predicting growth loss also tended to be significant for predicting total loss. Absolute loss was higher

Table 15. Regression model for total loss in basal area per acre

Model: $\ln(\text{basal area/acre} + 1) = 1.2354$
$-2.4045 \times 10^{-4} \times |\text{elevation} - 3700|$ (feet)
$+3.3733 \times 10^{-4} \times$ host volume/acre (cubic feet)
$+6.1871 \times 10^{-4} \times$ true fir volume/acre (cubic feet)
$-7.5131 \times 10^{-4} \times$ variance (stand height) (square feet)

$R^2 = 0.5167$ $\hat{\sigma}^2 = 0.3729$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	3.6259×10^{-2}	-1.0755×10^{-5}	-5.8366×10^{-6}	-3.7750×10^{-6}	-2.7003×10^{-5}
b_1		1.4401×10^{-8}	-4.4333×10^{-10}	3.3418×10^{-9}	4.9795×10^{-10}
b_2			3.3262×10^{-9}	-2.0653×10^{-9}	-3.1974×10^{-9}
b_3				2.0845×10^{-8}	-5.3647×10^{-9}
b_4					1.1794×10^{-7}

Comparison of estimators:

	χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}gm$
minimum	(1, 2100, 452, 0, 1287)	-0.08	0.11	0.02
mean	(1, 721, 2383, 381, 308)	5.49	6.82	6.80
maximum	(1, 0, 6777, 2049, 16)	117.72	142.05	133.51

Table 16. Regression model for total loss in volume per acre

Model:

$$
\begin{aligned}
\ln(\text{volume/acre} + 1) = {} & 3.8488 \\
& -5.2974 \times 10^{-4} \times |\text{elevation} - 3700| \quad \text{(feet)} \\
& +5.9425 \times 10^{-4} \times \text{host volume/acre} \quad \text{(cubic feet)} \\
& +1.8556 \times \frac{\text{true fir basal area}}{\text{host basal area}} \\
& -1.2473 \times 10^{-3} \times \text{variance (stand height)} \quad \text{(square feet)}
\end{aligned}
$$

$R^2 = 0.3442$ $\qquad \hat{\sigma}^2 = 1.7218$

Covariance matrix of parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	1.8315×10^{-1}	-5.1573×10^{-5}	-2.9563×10^{-5}	-8.6051×10^{-2}	-1.2184×10^{-4}
b_1		6.5194×10^{-8}	-2.9705×10^{-10}	2.1455×10^{-5}	4.4438×10^{-9}
b_2			1.4455×10^{-8}	4.0411×10^{-6}	-1.7561×10^{-8}
b_3				3.9202×10^{-1}	-3.3371×10^{-5}
b_4					5.4103×10^{-7}

Comparison of estimators:

	X'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}{}_{gm}$
minimum	(1, 2100, 452, 0, 1287)	3.05	8.59	5.36
mean	(1, 721, 2383, 0.18, 308)	124.98	296.98	290.88
maximum	(1, 0, 6777, 0.77, 16)	10847.60	25659.10	19099.90

Table 17. Regression model for total loss as a proportion of expected basal area per acre

Model: $\ln(\text{proportion basal area/acre} + 1) = 6.8954 \times 10^{-2}$

$-1.6887 \times 10^{-4} \times |\text{elevation} - 3700|$ (feet)

$+9.1052 \times 10^{-4} \times$ true fir basal area/acre (square feet)

$R^2 = 0.2563 \qquad \hat{\sigma}^2 = 0.001792$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2
b_0	8.2817×10^{-5}	-5.6902×10^{-8}	-1.1122×10^{-6}
b_1		6.9731×10^{-11}	3.9744×10^{-10}
b_2			4.9611×10^{-8}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}gm$
minimum (1, 2100, 0)	0.0341	0.0350	0.0349
mean (1, 721, 17)	0.0746	0.0755	0.0755
maximum (1, 0, 84)	0.1566	0.1576	0.1574

Table 18. Regression model for total loss as a proportion of expected volume per acre

Model:

$$\ln(\text{proportion volume/acre} + 1) = 8.8714 \times 10^{-2} - 2.7236 \times 10^{-5} \times |\text{elevation} - 3700| \ (\text{feet}) + 3.7643 \times 10^{-5} \times \text{true fir volume/acre (cubic feet)}$$

$R^2 = 0.2663$ $\hat{\sigma}^2 = 0.002142$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2
b_0	9.6257×10^{-5}	-6.6128×10^{-8}	-5.4486×10^{-8}
b_1		8.2380×10^{-11}	1.7641×10^{-11}
b_2			1.0967×10^{-10}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}_{gm}}$
minimum (1, 2100, 0)	0.0320	0.0331	0.0330
mean (1, 721, 381)	0.0870	0.0882	0.0881
maximum (1, 0, 2049)	0.1804	0.1817	0.1815

in stands close to 3,700 feet in elevation, in stands with a large amount of host, particular true fir, and in stands more uniform in height. Relative total loss models differ from growth loss models in that they do not contain any measure of variation in tree size.

Data fit for the total loss models was always poorer than the similar growth loss models. For example, the relative total loss models accounted for about 26 percent of the total variation while the relative growth loss models accounted for approximately 32 percent. This indicates that the loss associated with tree mortality could not be explained very well with the available set of predictor variables. More discussion on this point arises when mortality models are presented later in this section.

How these models can be used depends on the needs of the user. If all that is wanted is the ability to rank a set of stands in terms of their expected vulnerability to WBW, the models for predicting the log of damage can be used directly. Values for the appropriate stand characteristics of a particular stand are simply plugged into the equation and the resulting prediction of expected log damage is used to rank the stand for its vulnerability.

Basal area models should be preferred over volume models. Data for the former were based directly on diameter growth measurements while data for the latter required assumptions on the relationship between height and diameter reduction.

If actual estimates of expected loss are desired, a choice must be made as to which estimator to use. The unbiased estimator would give the most accurate answer; however it requires evaluating the sum of an infinite series and calculating the variance of the estimate ($\hat{\sigma}_{\hat{y}}^2$) for each stand. The approximation of Beauchamp and Olson (1973) described in

the models section does not require the infinite series to be evaluated although it does require the estimate variance. In my experience, the approximation is very close to the unbiased result; the small difference is more than offset by the reduction in difficulty in obtaining an answer. Of course, if the calculations are going to be done by computer this difference in amount of calculations may be of no consequence; in that case use of the unbiased estimator would be recommended.

The other two estimators do not require either the infinite series or the variance of the estimate to be evaluated. Of the two, that using sample estimates in place of population parameters ($e^{\hat{y} + \frac{1}{2}\hat{\sigma}^2}$) would be preferred as the bias is often substantially reduced at the cost of addition of a constant ($\hat{\sigma}^2$). As shown in the various regression model tables the amount of bias introduced by using this estimator is generally quite small. The models for absolute growth and total volume loss (Tables 12a, 12b and 16) appear to be exceptions where the bias introduced is substantial. Thus, if one desires estimates of volume loss either the unbiased estimator or Beauchamp and Olson's approximation should be used. Again if the procedure is going to be automated, I'd recommend the unbiased estimator.

To illustrate, let's assume we want to predict the expected growth loss in basal area per acre. Looking at the model in Table 11a we see that we need information on stand elevation, host volume per acre, true fir trees per acre and the variance of stand height. If values were 3,700 feet elevation, 6,777 cubic feet of host volume per acre, 215 true fir trees per acre and a height variance of 16, calculations would proceed as follows:

1) The prediction for the expected log (growth loss) is

$\hat{y}$ = ln(basal area/acre + 1) = 0.97258

$-0.00017831 \times |3{,}700 - 3{,}700| + 0.0003069 \times 6{,}777$

$+ 0.0045192 \times 215 - 0.00071975 \times 16$

$= 4.0125$

2) The biased estimate for expected loss is

$$\hat{z} + 1 = e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2} = \text{Exp}(4.0125 + 0.2027/2) = 61.19$$

Thus $\hat{z} = 60.19$ square feet/acre

3) The unbiased approximation is

$$\hat{z} + 1 = (e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2})\ \{1 - \frac{\hat{\sigma}^2(2\phi+\hat{\sigma}^2)}{4n} + \frac{(\hat{\sigma}^2)^2[(\hat{\sigma}^2)^2 + 2(16/3 + 2\phi)\hat{\sigma}^2 + 4\phi^2 + 16\phi]}{32n^2}\}$$

where $\phi = \hat{\sigma}^2_{\hat{y}}(\frac{n}{\hat{\sigma}^2})$

now $n = 77$

$\hat{\sigma}^2 = 0.2027$

and $\hat{\sigma}^2_{\hat{y}} = x'(X'X)^{-1}\ \hat{\sigma}^2 x$

$= (1, 0, 6777, 215, 16)\ (X'X)^{-1}\hat{\sigma}^2 x$

$= 0.07521$

Thus $\phi = 0.07521\ (77/0.2027) = 28.5701$

and $\hat{z}+1 = \text{Exp}(4.0125 + 0.2027/2) \times 0.9631 = 58.93$

Thus $\hat{z} = 57.93$

4) The unbiased estimate is

$$\hat{z} + 1 = e^{\hat{y}}\ g_m[\tfrac{m+1}{2m}(\hat{\sigma}^2 - \hat{\sigma}^2_{\hat{y}})]$$

where $g_m(t) = \sum_{i=0}^{\infty} \frac{m^i(m+2i)}{m(m+2)\cdots(m+2i)}\ (\frac{m}{m+1})^i\ \frac{t^i}{i!}$

now $m = n-(p+1) = 77 - 5 = 72$

$\hat{\sigma}^2 = 0.2027$

$\hat{\sigma}^2_{\hat{y}} = 0.07521$

Thus $g_m \doteq 1.06577$ [based on a convergence criterion of 10^{-8}]

and $\hat{z} + 1 = \text{Exp}(4.0125) \times 1.06577 = 58.92$

Thus $\hat{z} = 57.92$

B. Mortality and topkill models

Calculation of mortality and topkill rates did not require tree growth measurement. Thus, information was available for all 102 stands. The list of candidate predictor variables was identical to that for the growth loss variables, but data for an additional 25 stands was available. Descriptive statistics for these potential predictor variables are shown in Table 19.

Mortality rates were calculated in terms of trees per acre, basal area in square feet per acre, and volume in cubic feet per acre. Rates were also calculated as proportions of the total host component both live and dead: for example, the proportion of dead trees per acre was dead trees per acre/(live trees per acre + dead trees/acre). Topkill rates were calculated in terms of trees per acre and basal area per acre of trees with observed topkill. Again these rates were also expressed as proportions; in this case the proportion of trees with topkill was the number with topkill/total live host. Descriptive statistics for all these impact rates are shown in Table 20.

Detailed examination of the mortality data revealed a distribution characterized by a point mass at zero ($n_1 = 38$) and a range of positive values ($n_2 = 64$) strongly skewed to the right. The shape of the distribution of positive mortality values in terms of basal acre per acre is shown in the upper section of figure 3. The lower section of the figure shows the distribution following a natural logarithmic transformation. Kolmogorov-Smirnov tests for normality yielded D = 0.2500 and 0.2050 for the original and transformed data, respectively. While both tests indicated non-normality ($p<0.01$), the log transformation did tend to normalize the data.

The characteristics listed above describe the Δ distribution (Aitchison and Brown 1957) which was described in the methods section:

Table 19. Descriptive statistics for site and stand characteristics used as candidate predictor variables in topkill and mortality vulnerability models.

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
ELEV	ELEVATION (FEET)	102	3401.47058824	882.69770686	1600.00000000	5400.00000000
ASPECT	ASPECT (DEGREES)	102	199.86274510	116.84482722	1.00000000	360.00000000
SLOPE	PERCENT SLOPE	102	37.94117647	17.69310630	10.00000000	90.00000000
SITE	SITE VIGOR (HEIGHT/AGE FOR SITE TREES)	102	53.64117647	13.38419864	18.30000000	85.50000000
DENSE1	TOTAL TREES/ACRE	102	199.64215686	109.52558310	40.80000000	738.20000000
DENSE2	TOTAL BASAL AREA/ACRE (SQ.FT)	102	128.19411765	51.73287984	33.30000000	299.00000000
DENSE3	TOTAL VOLUME/ACRE (CU.FT)	102	3440.98627451	1647.61822623	539.70000000	9401.50000000
HOST1	PROPORTION OF TOTAL TREES IN HOST	102	0.76069608	0.19536950	0.02500000	1.00000000
HOST2	PROPORTION OF TOTAL BASAL AREA IN HOST	102	0.73876471	0.17766941	0.11300000	1.00000000
HOST3	PROPORTION OF TOTAL VOLUME IN HOST	102	0.73050000	0.17972469	0.14700000	1.00000000
HOST4	HOST TREES/ACRE	102	149.82417451	98.02315023	5.98500000	564.65550000
HOST5	HOST BASAL AREA/ACRE (SQ.FT)	102	95.58385588	46.70383916	14.01200000	227.91200000
HOST6	HOST VOLUME/ACRE (CU.FT)	102	2557.16559039	1459.24955100	387.06180000	7014.28260000
COMP1	TRUE FIR TPA/HOST TPA	102	0.21968627	0.28007312	0.00000000	0.86900000
COMP2	TRUE FIR BA/HOST VOLUME	102	0.17308824	0.22974080	0.00000000	0.77400000
COMP3	TRUE FIR VOLUME/HOST TPA	102	0.15614706	0.21284426	0.00000000	0.78700000
COMP4	TRUE FIR TREES/ACRE	102	36.25083303	53.81072646	0.00000000	274.32929610
COMP5	TRUE FIR BASAL AREA/ACRE (SQ.FT)	102	17.33418732	24.03719691	0.00000000	125.78631000
COMP6	TRUE FIR VOLUME/ACRE (CU.FT)	102	404.62375445	569.06720962	0.00000000	3179.10782350
MEAN_HD	MEAN DIAMETER--HOST TREES	102	10.43598039	2.28639422	7.31000000	21.11000000
MEAN_HH	MEAN HEIGHT--HOST TREES	102	62.85352941	11.70967398	39.39000000	90.70000000
MEAN_SD	MEAN DIAMETER--STAND TREES	102	10.38941176	2.13270451	7.40000000	18.30000000
MEAN_SH	MEAN HEIGHT--STAND TREES	102	62.60892157	11.25107819	37.59000000	92.16000000
VAR_HD	VARIANCE IN DIAMETER--HOST TREES	102	21.08372549	11.20535674	3.34000000	59.55000000
VAR_HH	VARIANCE IN HEIGHT--HOST TREES	102	333.71107843	202.05665291	14.51000000	1126.29000000
VAR_SD	VARIANCE IN DIAMETER--STAND TREES	102	22.52784314	12.09320705	4.62000000	62.33000000
VAR_SH	VARIANCE IN HEIGHT--STAND TREES	102	347.59852941	217.11634892	16.25000000	1286.73000000

Table 20. Descriptive statistics for topkill and mortality data.

VARIABLE	LABEL	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
TKILL1	HOST TREES/ACRE WITH TOPKILL	102	11.59411765	20.61984024	0	94.40000000
TKILL2	PROPORTION OF HOST TREES WITH TOPKILL	102	0.08062745	0.13487412	0	0.64200000
TKILL3	HOST BASAL AREA/ACRE WITH TOPKILL	102	5.60196078	9.67397223	0	45.50000000
TKILL4	PROPORTION OF HOST BA WITH TOPKILL	102	0.05707843	0.09535112	0	0.53300000
MORTAL1	DEAD HOST TREES/ACRE	102	6.55000000	13.37338683	0	85.80000000
MORTAL2	PROPORTION OF HOST TREES DEAD	102	0.03573529	0.06009496	0	0.33800000
MORTAL3	DEAD HOST BASAL AREA/ACRE	102	3.95686275	6.88644112	0	44.00000000
MORTAL4	PROPORTION OF HOST BASAL AREA DEAD	102	0.03264706	0.04467720	0	0.18800000
MORTAL5	DEAD HOST VOLUME/ACRE	102	107.40098039	211.82203136	0	1619.10000000
MORTAL6	PROPORTION OF HOST VOLUME DEAD	102	0.03748039	0.04624017	0	0.21400000

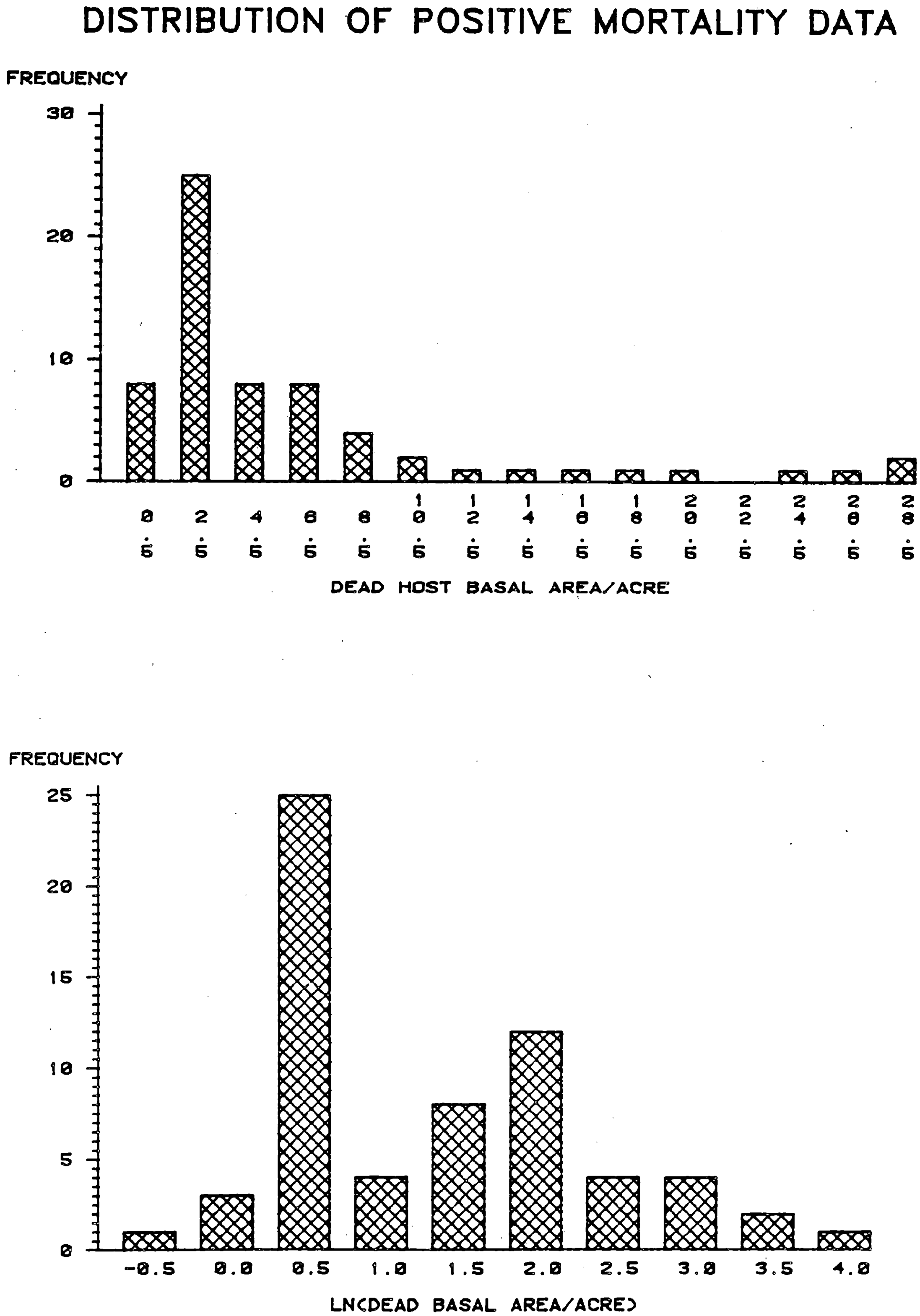


Figure 3. Histograms of non-zero data values (n=64) for host mortality in basal area per acre. The upper figure shows the distribution of the original data while the lower figure shows the distribution following a natural log transformation.

$z \sim \Delta\ (\delta, \mu, \sigma)$

where δ = probability of no mortality

and μ, σ are parameters of the normal distribution for

$\ln(z)$, $z>0$

A model for predicting δ was developed by classifying all stands as either having or not having mortality and fitting an equation to that data using logistic regression. Six models, one for each expression of mortality, were fit to all positive mortality values using the same regression techniques used for the growth and total loss model development.

The logistic regression model for probability of mortality is shown in Table 21. Probability of mortality increases as the total amount of host volume and the proportion of that volume in true fir increase. Thus a stand with a large volume of true fir would be most likely to sustain some WBW-caused mortality.

The "fit" of this model is shown in the lower section of Table 21. Using a predicted probability of 0.525 as the break point between stands without and with mortality, the model was able to correctly classify 52 out of 64 stands with mortality and 27 out of 38 stands with no mortality for a total of 77.45 percent correctly classified. Although one might expect a cut point of 0.5 to give the best classification results, that value resulted in only 74.5 percent of the stands classified correctly.

The regression models based on the data from the 64 stands with positive mortality are displayed in Tables 22 through 27 with the first three tables showing the models for absolute mortality in trees per acre, square feet basal arce per acre and cubic feet volume per acre and the latter three displaying the equivalent relative mortality models. Significant predictor variables are host basal area per acre, true fir volume per acre and a trignometric function of aspect.

Table 21. Logistic regression model for the probability of mortality in a stand

Model: Probability (mortality) $= \dfrac{1}{1 + e^{-\chi b}}$

where $\chi b = -2.06 + 0.000936 \times$ host volume/acre (cubic feet)

$+ 3.03 \times$ (true fir volume/host volume)

Classification results:

Cutpoint	Percent correctly classified		
	No mortality	Mortality	Total
0.475	60.53	85.94	76.47
0.525	71.05	81.25	77.45
0.575	73.68	78.13	76.47

Table 22. Regression model for mortality in trees per acre

Model: ln(trees/acre) = 2.5014×10^{-1}
$+5.5061 \times 10^{-1} \times \cos(\text{aspect})$
$-3.0177 \times 10^{-1} \times \sin(\text{aspect})$
$+7.4754 \times 10^{-3} \times$ host basal area/acre (square feet)
$+7.2391 \times 10^{-4} \times$ true fir volume/acre (cubic feet)

$R^2 = 0.3373$ $\hat{\sigma}^2 = 1.1504$

Covariance matrix of parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	0.1335	-1.4224×10^{-2}	-4.0398×10^{-3}	-1.0296×10^{-3}	1.7390×10^{-6}
b_1		3.6260×10^{-2}	-8.6133×10^{-3}	5.6091×10^{-5}	-1.0445×10^{-6}
b_2			5.0193×10^{-2}	6.8834×10^{-5}	-1.1772×10^{-5}
b_3				1.0625×10^{-5}	-2.7712×10^{-7}
b_4					5.4921×10^{-8}

Comparison of estimators:

X'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}gm$
minimum (1, -0.88, 0.48, 34, 0)	0.882	1.568	1.455
mean (1, 0.26, 0.10, 109, 546)	4.829	8.584	8.464
maximum (1, 0.88, -0.48, 226, 3179)	130.995	232.842	186.237

Table 23. Regression model for mortality in basal area per acre

Model: $\ln(\text{basal area/acre}) = 1.0979 \times 10^{-1}$
$+2.9184 \times 10^{-1} \times \cos(\text{aspect})$
$+2.0657 \times 10^{-1} \times \sin(\text{aspect})$
$+1.0399 \times 10^{-2} \times \text{host basal area/acre (square feet)}$

$R^2 = 0.2940$ $\hat{\sigma}^2 = 0.6755$

Covariance matrix of parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	7.8355×10^{-2}	-8.3323×10^{-3}	-2.1532×10^{-3}	-5.9939×10^{-4}
b_1		2.1279×10^{-2}	-5.1889×10^{-3}	2.9840×10^{-5}
b_2			2.7990×10^{-2}	5.5406×10^{-6}
b_3				5.4178×10^{-6}

Comparison of estimators:

X'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}_{gm}$
minimum (1, -0.82, -0.58, 34)	1.110	1.556	1.495
mean (1, 0.26, 0.10, 109)	3.829	5.367	5.330
maximum (1, 0.82, 0.58, 226)	16.873	23.652	22.467

Table 24. Regression model for mortality in volume per acre

$$\begin{aligned}\text{Model: } \ln(\text{volume/acre}) = \; & 3.3099 \\ & +1.9979 \times 10^{-1} \times \cos(\text{aspect}) \\ & +2.8321 \times 10^{-1} \times \sin(\text{aspect}) \\ & +1.0912 \times 10^{-2} \times \text{host basal area/acre (square feet)}\end{aligned}$$

$R^2 = 0.2712 \qquad \hat{\sigma}^2 = 0.8128$

Covariance matrix of parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	9.4690×10^{-2}	-9.5955×10^{-3}	-2.7783×10^{-3}	-7.2317×10^{-4}
b_1		$2.6059 \times 10-2$	-6.4417×10^{-3}	3.3851×10^{-5}
b_2			3.3766×10^{-2}	7.5614×10^{-6}
b_3				6.5284×10^{-6}

Comparison of estimators:

X'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}_{gm}}$
minimum (1, -0.58, -0.82, 34)	28.02	42.06	40.08
mean (1, 0.25, 0.11, 109)	97.85	146.92	145.60
maximum (1, 0.58, 0.82, 226)	459.95	690.57	647.94

Table 25. Regression model for mortality in proportion of trees per acre

Model: ln(proportion of trees/acre) = -3.7372
+5.6279 x 10^{-4} x true fir volume/acre (cubic feet)

R^2 = 0.1065 $\hat{\sigma}^2$ = 1.0805

Covariance matrix of parameter estimates $[(X'X)^{-1}\sigma]$:

	b_0	b_1
b_0	2.9665 x 10^{-2}	-2.3407 x 10^{-5}
b_1		4.2866 x 10^{-8}

Comparison of estimators:

X'		$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}gm$
minimum	(1, 0)	0.0238	0.0409	0.0401
mean	(1, 546)	0.0324	0.0556	0.0549
maximum	(1, 3179)	0.1426	0.2445	0.2087

Table 26. Regression model for mortality in proportion of basal area per acre

Model: $\ln(\text{proportion of basal area/acre}) = -3.5300$
$+2.7201 \times 10^{-1} \times \cos(\text{aspect})$
$+1.5096 \times 10^{-1} \times \sin(\text{aspect})$
$+2.7640 \times 10^{-4} \times \text{true fir volume/acre (cubic feet)}$

$R^2 = 0.1435 \qquad \hat{\sigma}^2 = 0.6054$

Covariance of matrix of parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	1.7751×10^{-2}	-4.6246×10^{-3}	1.3840×10^{-3}	-1.3215×10^{-5}
b_1		1.8924×10^{-2}	-4.7235×10^{-3}	2.2017×10^{-7}
b_2			2.6177×10^{-2}	-5.2497×10^{-6}
b_3				2.5096×10^{-8}

Comparison of estimators:

X'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}_{gm}}$
minimum (1, -0.87, -0.49, 0)	0.0215	0.0291	0.0284
mean (1, 0.26, 0.10, 546)	0.0372	0.0503	0.0500
maximum (1, 0.87, 0.49, 3179)	0.0963	0.1303	0.1189

Table 27. Regression model for mortality in proportion of volume per acre

Model: $\ln(\text{proportion of volume/acre}) = -3.4377 + 2.8093 \times 10^{-1} \times \cos(\text{aspect}) + 2.7633 \times 10^{-1} \times \sin(\text{aspect})$

$R^2 = 0.1066$ $\hat{\sigma}^2 = 0.7706$

Covariance matrix of parameter estimates $[(X'X)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2
b_0	1.3825×10^{-2}	-5.5423×10^{-3}	-1.8400×10^{-3}
b_1		2.4540×10^{-2}	-6.1445×10^{-3}
b_2			3.2005×10^{-2}

Comparison of estimators:

X'		$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}gm$
minimum	(1, -0.71, -0.70)	0.0217	0.0319	0.0311
mean	(1, 0.25, 0.11)	0.0355	0.0522	0.0518
macimum	(1, 0.71, 0.70)	0.0476	0.0700	0.0690

Relationships parallel those found for growth loss; absolute mortality was heaviest in stands with a large amount of host biomass particularly if the host were true fir. The host biomass term was not significant in any of the relative mortality models indicating that mortality was constant per unit of host across the levels of host sampled in this study; again this is similar to trends in growth impact.

Data fit was generally poor; the models for relative mortality only accounted for 11 to 15 percent of the total variation. Due to the large number of uncontrolled factors that influence mortality (tree condition previous to outbreak, occurrence of other damaging agents) this large unexplained variation is expected.

The similarity in trends to those found for growth loss and the lack of good fit explains the results from analysis of total loss. Since the significant relationships of both mortality and growth to site and stand factors were similar, the same variables were useful in modeling total loss. The decrease in data fit from growth loss models to total loss models reflects the increased unexplained variation associated with mortality loss.

The other factor related to mortality is stand aspect. Based on the parameter estimates for cosine and sine transformations of aspect, maximum mortality appears to occur on northerly aspects. Actual maximums range from 331° for the model in Table 22 to 55° for the model in Table 24 (see Stage 1976 for calculation details).

Similar considerations as those used for the growth and total loss models need to be made in choosing the proper estimator for expected mortality. Use of the unbiased estimator or its approximation appear necessary to obtain reasonable estimates in terms of trees per acre (Table 22) or proportion of host trees per acre (Table 25). For other models the bias introduced by using $e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$ does not seem overly large.

To obtain an estimate of expected mortality for a particular stand, both the logistic model for probability of mortality (Table 21) and the appropriate mortality regression model would have to be used. For example, if an estimate of expected mortality in basal area per acre were desired, the logistic model and the model in Table 23 would be necessary. Thus, data would be needed on host volume per acre and the proportion of host volume in true fir for the probability model and stand aspect and host basal area per acre for the regression model.

Let's assume we have a stand on a southeast aspect (135°) with a host basal area of 110 square feet and a host volume of 2,600 cubic feet and with 20 percent of host volume in true fir. Based on these numbers the expected basal area per acre mortality would be calculated as follows:

$$\text{Probability (mortality)} = [1 + \text{Exp}(-xb)]^{-1}$$

$$\text{where } xb = -2.06 + 0.000936 \times 2{,}600 + 3.03 \times 0.2$$
$$= 0.9796$$

$$\text{Thus probability (mortality)} = [1 + \text{Exp}(-0.9796)]^{-1} = 0.7270$$

$$\text{Now } \ln(\text{mortality}) = 0.10979 + 0.29184 \times \cos(135)$$
$$+ 0.20657 \times \sin(135) + 0.010399 \times 110$$
$$= 1.1934$$

$$\text{Thus predicted mortality} = \text{Exp}(1.1934 + 0.6755/2)$$
$$= 4.6234$$

[Note: I have used the formula $\hat{z} = e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$]

Therefore, the expected mortality in that stand is

probability (mortality) x predicted mortality

= 0.7270 x 4.6234 = 3.36 square feet per acre

Distribution of topkill values was similar to that of mortality data--a point mass of zero ($n_1 = 52$) and a range of positive values ($n_2 = 50$) skewed to the right. The upper histogram in figure 4 shows

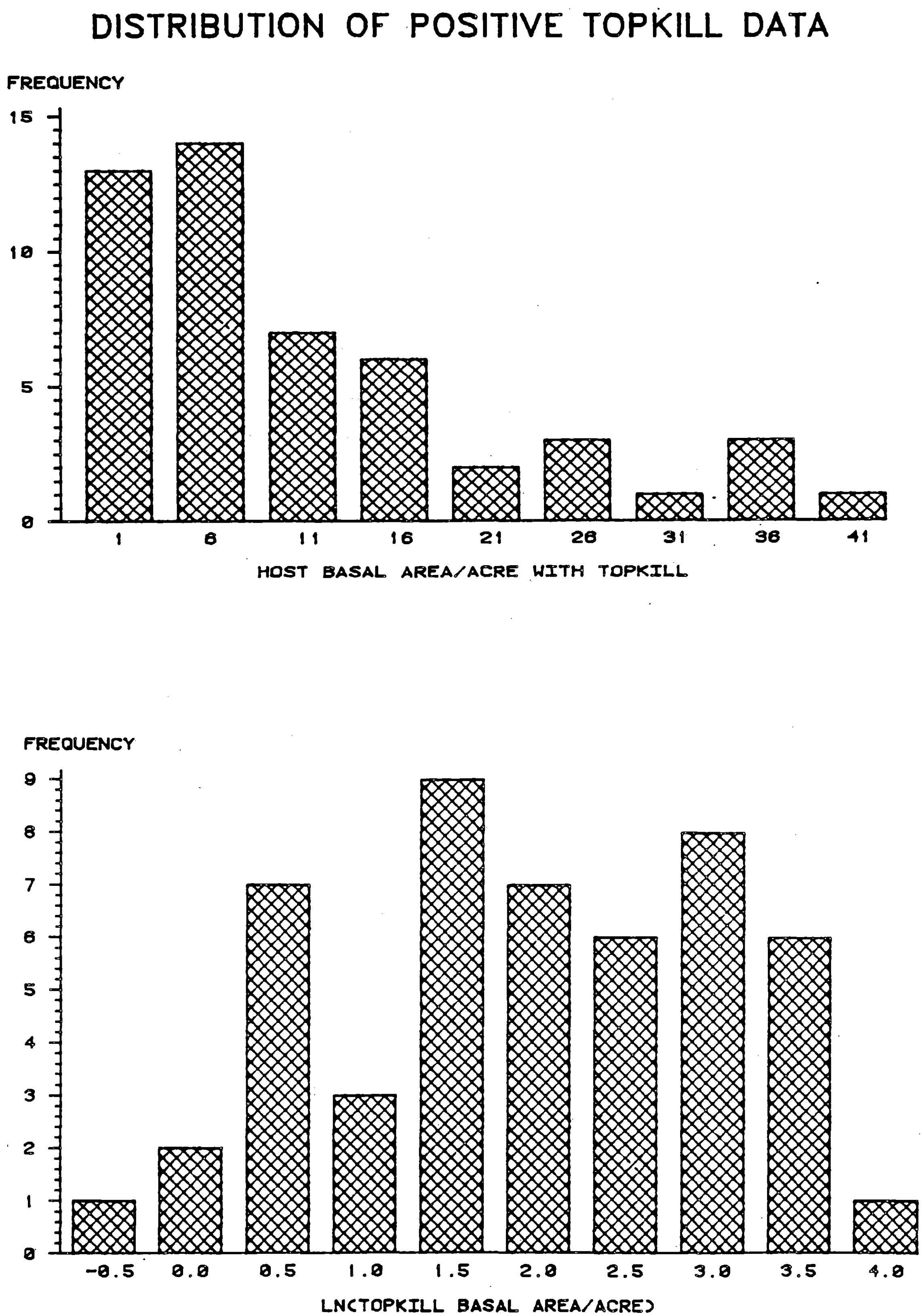


Figure 4. Histograms of non-zero data values (n=50) for basal area per acre of host with topkill. The upper figure shows the distribution of the original data, while the lower figure shows the distribution following a natural log transformation.

the distribution of positive topkill values in basal area per acre; the distribution was found to be non-normal (Wilks-Shapiro W = 0.8242, $p<0.01$). The lower histogram show the distribution of the same data following a natural log transform; the transformation successfully normalized the data (W = 0.9553, p = 0.107). Thus the Δ distribution was the appropriate choice for modeling this data as it was for the mortality data.

The logistic model for estimating the probability of topkill is shown in Table 28. Estimates of model parameters indicate that the chance that topkill will occur in a stand increases as the steepness of the slope, the number of true fir trees per acre and the average diameter of the stand increase. Maximum probability of topkill occurred on westerly aspects and on sites with a vigor rating (50 x height/age) of 35. The model was able to correctly classify 42 out of 52 stands that lack any topkill and 37 out of 50 stands with topkill for an overall rate of 77.45 percent correctly classified. As with the model for probability of mortality, cutpoints for deciding whether or not a stand would sustain topkill other than 0.5 were able to correctly classify more stands.

Regression models for predicting the amount of topkill likely to occur are presented in Tables 29 through 32, the first two showing the models for trees per acre and basal area per acre of trees with topkill and the second two showing the models for the proportion of host with topkill. A quadratic expression of site vigor with a maximum at 43 was common to all models, indicating that the rate of topkill was lower on both low productivity and high productivity sites than on sites with moderate productivity. Topkill increased as the volume of true fir increased indicating, as for growth loss and mortality, that true fir

Table 28. Logistic regression model for the probability of topkill in a stand

Model: Probability (topkill) $= \dfrac{1}{1 + e^{-\chi b}}$

where $\chi b = -8.05 + 0.0278 \times \text{percent slope}$
$+ 2.2086 \times \tan(\text{slope}) \times \cos(\text{aspect} + 75.69°)$
$+ 0.123 \times \text{site index} - 0.00174 \times (\text{site index})^2$
$+ 0.0171 \times \text{true fir trees/acre}$
$+ 0.485 \times \text{mean stand dbh (inches)}$

Classification results:

	Percent correctly classified		
Cutpoint	Not topkilled	Top Killed	Total
0.475	75.00	80.00	77.45
0.492	80.77	76.00	78.43
0.608	94.23	66.00	80.39

Table 29. Regression model for trees per acre with topkill

Model: $\ln(\text{trees/acre}) = -3.8393$
$+2.9286 \times 10^{-1} \times$ site index (feet @ 50 years)
$-3.3653 \times 10^{-3} \times (\text{site index})^2$
$+8.4561 \times 10^{-4} \times$ true fir volume/acre (cubic feet)

$R^2 = 0.4680$ $\hat{\sigma}^2 = 1.1802$

Covariance matrix of paramter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3
b_0	3.9622	-1.5976×10^{-1}	1.5344×10^{-3}	3.3877×10^{-5}
b_1		6.7247×10^{-3}	-6.6651×10^{-5}	-2.5102×10^{-6}
b_2			6.7951×10^{-7}	2.3520×10^{-8}
b_3				5.2918×10^{-8}

Comparison of estimators:

χ		$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}_{gm}}$
minimum	(1, 71, 5083, 0)	0.933	1.683	1.507
mean	(1, 50, 2630, 564)	11.455	20.667	20.287
maximum	(1, 43, 1849, 3179)	184.650	333.145	272.366

Table 30. Regression model for basal area per acre of trees with topkill

Model: $\ln(\text{basal area/acre}) = -4.7797$
$+1.7119 \times 10^{-2} \times$ slope (%)
$+1.5672 \times 10^{-1} \times$ site index (feet @ 50 years)
$-1.8078 \times 10^{-3} \times$ (site index)^2
$+1.9327 \times$ host volume/total volume
$+9.9719 \times 10^{-2} \times$ mean host dbh (inches)
$+6.0893 \times 10^{-4} \times$ true fir volume/acre (cubic feet)

$R^2 = 0.4667$ $\hat{\sigma}^2 = 0.7011$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4	b_5	b_6
b_0	3.5983	-1.3905×10^{-4}	-1.1296×10^{-1}	1.1012×10^{-1}	-3.1435×10^{-1}	-5.1409×10^{-2}	-2.7419×10^{-5}
b_1		5.7361×10^{-5}	-4.8450×10^{-5}	5.2486×10^{-7}	-1.5564×10^{-3}	4.0250×10^{-7}	3.3322×10^{-8}
b_2			4.6925×10^{-3}	-4.6730×10^{-5}	-1.0159×10^{-2}	1.0287×10^{-3}	-8.5267×10^{-7}
b_3				4.7672×10^{-7}	9.7819×10^{-5}	-1.0660×10^{-5}	7.2598×10^{-9}
b_4					7.8800×10^{-1}	1.6855×10^{-3}	1.2343×10^{-5}
b_5						2.3210×10^{-3}	1.9418×10^{-6}
b_6							3.3265×10^{-8}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}{}_{gm}$
minimum (1,20,71,5083,0.4,8,0)	0.41	0.58	0.50
mean (1,41,50,2630,0.8,11,564)	6.90	9.80	9.70
maximum (1,70,43,1849,1.0,21,3199)	306.90	435.75	307.85

Table 31. Regression model for proportion of trees per acre with topkill

Model: ln(proportion of trees/acre) = -9.8679
+2.9930 x 10^{-1} x site index (feet @ 50 years)
-3.4978 x 10^{-3} x (site index)^2
+1.2585 x 10^{-1} x mean host dbh (inches)
+5.5861 x 10^{-4} x true fir volume/acre (cubic feet)

R^2 = 0.4187 $\hat{\sigma}^2$ = 1.1402

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2	b_3	b_4
b_0	5.6309	-1.9187×10^{-1}	1.8708×10^{-3}	-8.2432×10^{-2}	-3.5271×10^{-5}
b_1		7.2780×10^{-3}	-7.2475×10^{-5}	1.7160×10^{-3}	-1.0095×10^{-6}
b_2			7.4013×10^{-7}	-1.7757×10^{-5}	8.0738×10^{-9}
b_3				3.7685×10^{-3}	3.1087×10^{-6}
b_4					5.3687×10^{-8}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}_{gm}$
minimum (1, 71, 5083, 8, 0)	0.0049	0.0087	0.0074
mean (1, 50, 2630, 11, 564)	0.0916	0.1620	0.1591
maximum (1, 43, 1849, 21, 3179)	2.6303	4.6515	2.8302

Table 32. Regression model for proportion of basal area per acre in trees with topkill

Model: ln(proportion of basal area/acre) = -6.3473

$+1.8984 \times 10^{-1} \times$ site index (feet @ 50 years)

$-2.1818 \times 10^{-3} \times$ (site index)^2

$R^2 = 0.2366$ $\qquad \hat{\sigma}^2 = 0.8240$

Covariance matrix of parameter estimates $[(\chi'\chi)^{-1}\hat{\sigma}^2]$:

	b_0	b_1	b_2
b_0	2.7512	-1.1042×10^{-1}	1.0608×10^{-3}
b_1		4.6121×10^{-3}	-4.5757×10^{-5}
b_2			4.6714×10^{-7}

Comparison of estimators:

χ'	$e^{\hat{y}}$	$e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$	$e^{\hat{y}}_{gm}$
minimum (1, 71, 5083)	0.0202	0.0305	0.0283
mean (1, 50, 2630)	0.0752	0.1136	0.1123
maximum (1, 43, 1849)	0.1088	0.1643	0.1616

species were more subject to topkill than Douglas-fir. This result had already been documented in Table 3. Other apparent trends show topkill increasing as the amount of host, the average host diameter and the steepness of the slope increase.

As was done with the mortality models, an estimate of topkill for a particular stand would be obtained by multiplying the estimated probability of topkill from the logistic model times the estimate of topkill rate from the chosen rate model. While data fit for the rate models was reasonable, variability tended to be fairly large. Thus variance estimates were also large, leading to potential bias problems. To counteract this, the unbiased estimator or Beauchamp and Olson's approximation are recommended, except for the model for proportion of basal area with topkill (Table 32) where the estimator $e^{\hat{y}+\frac{1}{2}\hat{\sigma}^2}$ appears to give adequate results.

Comparisons of Impacts With Other Ratings

A. Aerial survey ratings

Aerial sketch maps of WBW infestations have been done on an annual basis over the area covered in this study. These ratings have a number of failings: they cannot detect low levels of defoliation and often are inaccurate in boundary location. Despite these failings, aerial sketch maps have proved to be a useful tool for evaluating the extent of an outbreak and in defining areas for control projects. In the present study, the number of years a stand was noted as having detectable levels of defoliation was used as a stratification device for separating non-outbreak and outbreak stands.

Correlations between aerial ratings and indices of WBW impact were made to see how accurately the rating technique was able to project actual damage. Two ratings for each stand were constructed from the

aerial sketch map data: in the first, the number of years of noted defoliation from 1971 to 1980 was recorded while in the second rating the number of years from the first to the last year of noted defoliation inclusive was calculated. For example, if aerial sketch maps indicated a stand was defoliated in 1971 and 1980 but not in any year in between, that stand would receive an actual years rating of 2 and an inclusive years rating of 10. The second rating was made because of concern that the sketch maps might miss new defoliation in stands previously defoliated.

The inclusive number of years rating was less correlated to WBW damage than the actual number of years for all indices of damage (growth loss, total loss, mortality and topkill). Figure 5 shows the relationship between growth loss in basal area per acre and actual number of years of visible defoliation; simple correlation was 0.4766. The relationship appears to be fairly tight at the extremes of the aerial rating scale; most stands with 0 or 1 years of defoliation had low growth loss while stands with 8 or 9 years had high loss rates. For stands with intermediate aerial ratings (2 to 7 years) the growth loss data is more variable but a trend of increasing loss with increasing number of years of defoliation is still evident.

Occurrence of similar trends for other damage indices is shown in Figure 6 for total loss, in Figure 7 for mortality and in Figure 8 for topkill. Correlation coefficients were 0.4569, 0.2817 and 0.5686, respectively. The poor correlation with mortality can be seen to result from the high variability in mortality rates in stands with more than one year of visible defoliation. The pattern seems to indicate that, while high mortality occurs only in stands where a number of years of visible defoliation have been detected, low mortality rates are found in stands with all levels of visible defoliation. This pattern also

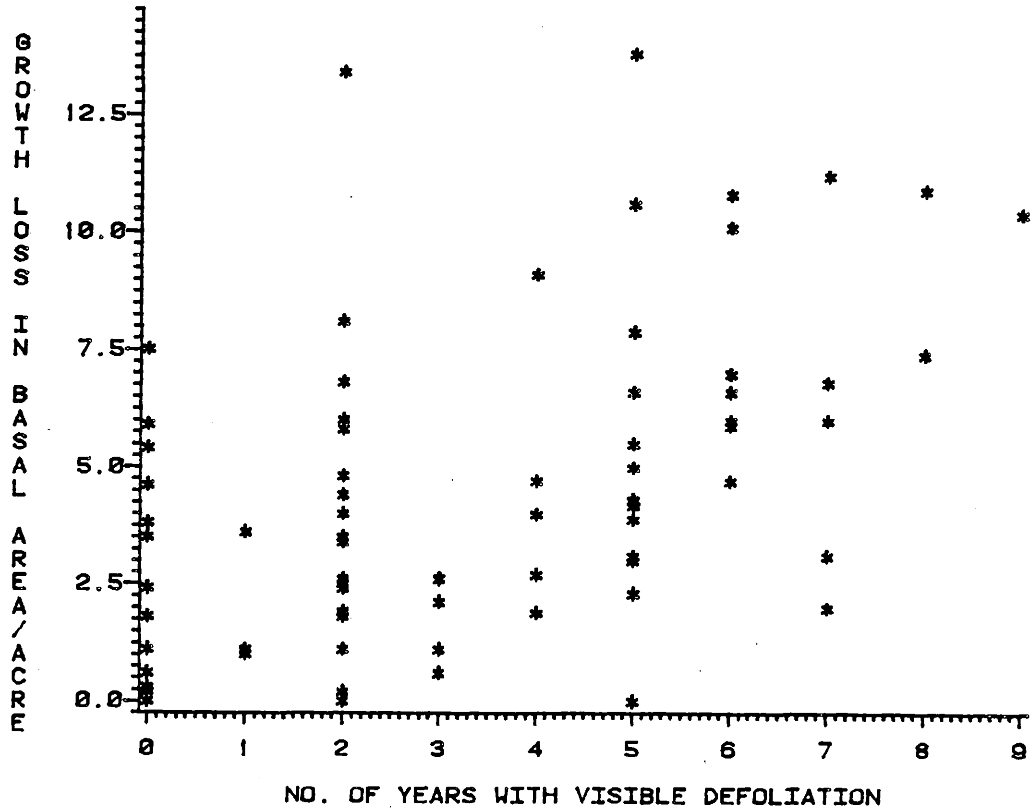


Figure 5. Relation of square feet basal area per acre growth loss to the number of years that aerial surveys detected visible WBW defoliation for each stand (n = 77)

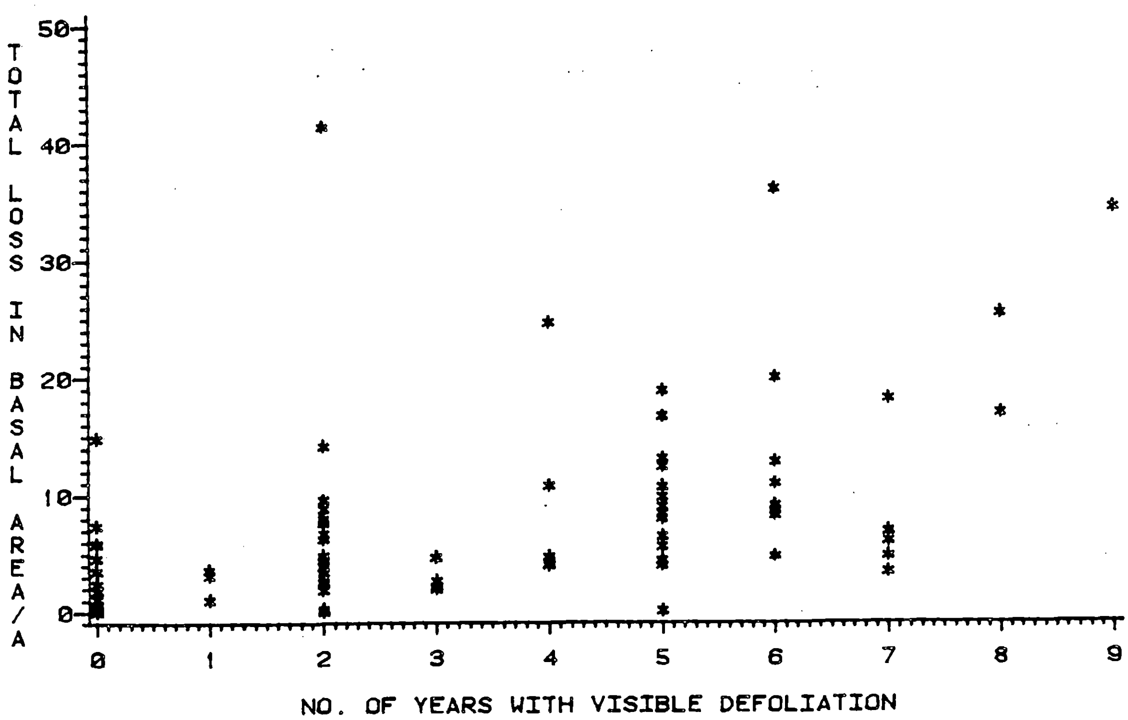


Figure 6. Relation of square feel basal area per acre total loss (growth loss and mortality) to the number of years that aerial surveys detected visible WBW defoliation for each stand (n = 77).

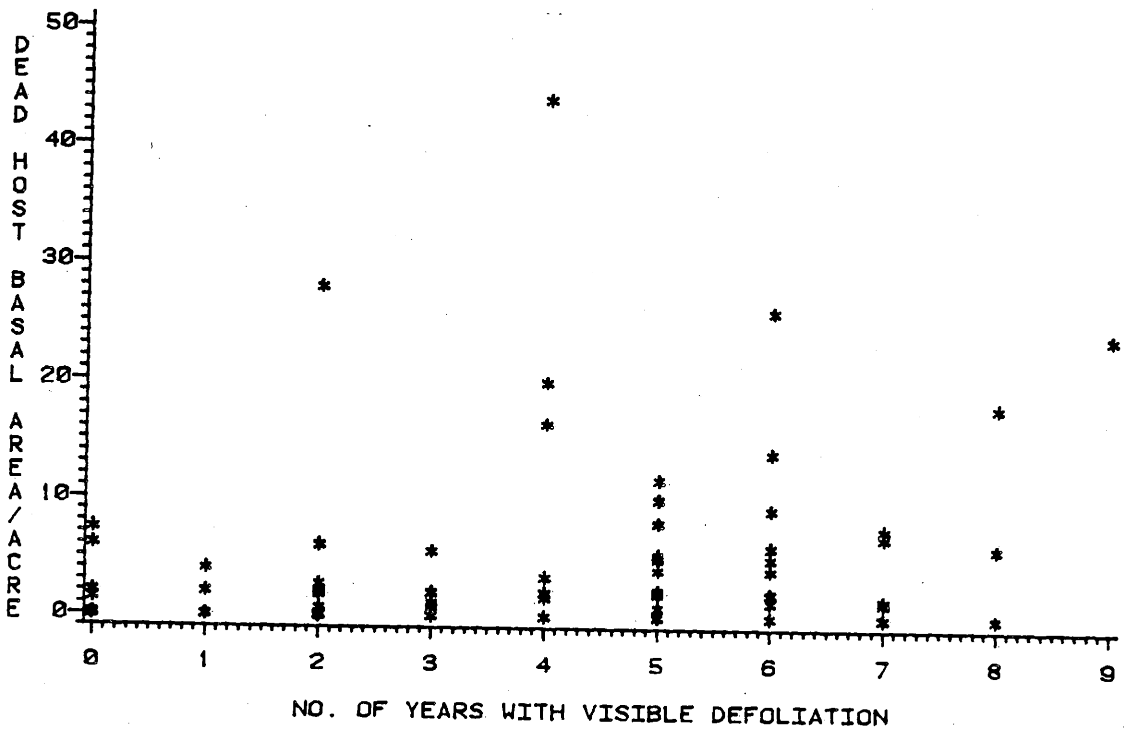


Figure 7. Relation of square feet basal area per acre in mortality to the number of years that aerial surveys detected visible WBW defoliation for each stand (n = 102).

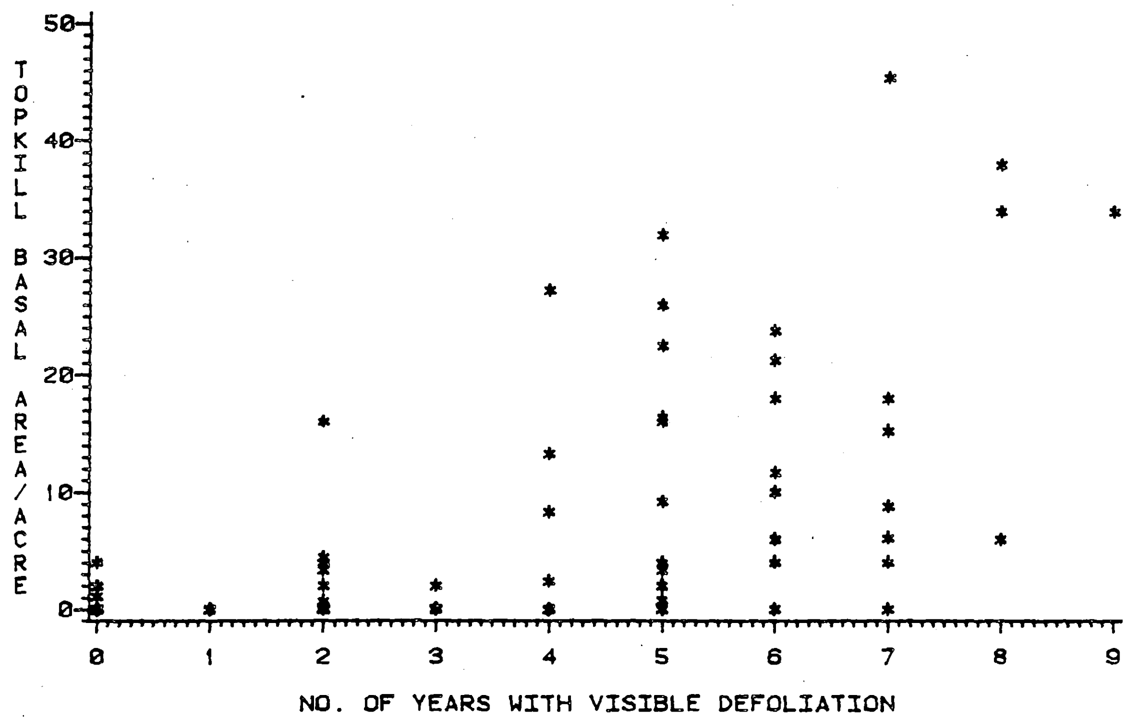


Figure 8. Relation of square feet basal area per acre of trees with topkill to the number of years that aerial surveys detected visible WBW defoliation for each stand (n = 102).

seems to hold for topkill rates. In addition, the maximum topkill rate associated with each defoliation class appears to be a linear function of the number of years of visible defoliation; this trend would account for the fairly strong correlation between topkill and years of defoliation.

B. Risk rating models

A number of studies have been conducted aimed at developing stand risk rating models for the WBW. These included models using aerial photo interpretation and remote sensing techniques to obtain the predictor variables (Heller et. al. 1981, Ulliman and Kessler 1983) and others based on ground surveys (Stoszek and Mika 1983). It was felt that the data from the present study would provide a good test for validity of these models.

Several obvious limitations on the utility of this data for testing purposes exist. The risk rating models mentioned above are all based on stand susceptibility--the rate of occurrence of budworm outbreaks--either measured as a defoliation level or denoted by the presence or absence of an outbreak. Thus these models attempt to rank stands for their suitability for budworm outbreak. The damage data gathered in the present study is not a direct measure of the insect but rather a measure of the interaction between insect and tree. While a non-susceptible (low risk) stand will not have any damage, a susceptible (high risk) stand may also not have appreciable damage due to the ability of the trees to overcome the effects of defoliation. This should be particularly true for mortality where the condition of the tree previous to defoliation should strongly influence the likelihood of death. Thus we might expect mortality effects to be poorly correlated with stand risk.

A second limitation lies in the type of data collected for this study. Each of the risk rating models requires a certain set of measure-

ments to generate risk predictions all of which were not measured in the present study. For example, the models of Stoszek and Mika (1983) require knowledge of the vegetation series (sensu Daubenmire and Daubenmire 1963), data not collected in this study.

Finally, the selection criteria used to choose stands for the present study created certain peculiarities in the range of conditions sampled. All stands have large host components with over 90 percent having at least half their basal area in host type; thus stands with small amounts of host are poorly represented. Additionally, one sampling stratum consists of stands sprayed to control budworm. It is reasonable to expect that the damage levels in these stands, already the highest in the survey, would have been higher still under untreated conditions.

Comparisons between damage and predicted stand risk were made using risk rating models developed by Anderson (1981) for the area around Twisp, Washington. These models were chosen primarily because of the close proximity of the area of the models' applicability to the present study area. Thus, particular values for physical site attributes such as elevation and aspect should reflect the same conditions in both studies. This is almost certainly not the case for the risk rating models developed in central Idaho; a particular elevation near McCall, Idaho does not represent similar conditions as that same elevation near Twisp.

Three models were evaluated, all predicting percent defoliation expected in the stand:

1) $\hat{y} = -570.67871 + 0.4242251 \times \text{elevation} - 9.0274 \times 10^{-5} \times \text{elevation}^2 + 5.94 \times 10^{-9} \times \text{elevation}^3$

2) $\hat{y} = 87.8364 - 0.0195628 \times \text{elevation} + 52.983 \times \text{purity}$

and 3) $\hat{y} = -580.78812 + 0.409854 \times \text{elevation} - 8.8574 \times 10^{-5} \times \text{elevation}^2 + 5.92 \times 10^{-9} \times \text{elevation}^3 + 49.446 \times \text{purity}$

Purity was originally defined as the proportion of total tree cover in host species; here I used proportion of basal area. Anderson's fourth model was not evaluated as it required information on stand closure--data which was not available.

Correlation between the predictions obtained from the three models and various measures of budworm impact are displayed in Table 33. Best correlation was obtained with model 3, the most complicated model involving a cubic function of elevation and a positive linear function of purity. The predictions from model 3 showed significant ($\alpha = 0.05$) positive correlation with all impact variables. Model 1 which involves only a cubic function of elevation showed a similar pattern although the correlation with mortality was not significant. Model 2 involving linear functions of elevation and purity failed to show significant correlation with any impact variable.

Scattergrams of associated impacts and predicted defoliation values (risk) are shown in Figures 9 through 12. Correlation was strongest between basal area growth loss and predicted risk (Figure 9); a clear trend of increasing impact with increasing risk can be seen. Mortality (Figure 11) showed the poorest correlation; the positive correlation results from consistent low impacts at low risk levels coupled with high impacts being only associated with high risk. Correlation for total loss (Figure 10) is intermediate to growth loss and mortality as would be expected. Topkill (Figure 12) appears to have the same pattern as mortality although correlation is much stronger; presumably this results from the greater number of high impact stands at the high risk levels.

Table 33. Pearson product-moment correlations between stand impacts and predicted risk obtained from Anderson's models.

	Predictions from Anderson's models		
Impact	Model 1	Model 2	Model 3
Basal area growth loss (n=77)	0.2663	-0.0340	0.3359
Basal area total loss (n=77)	0.2503	-0.0801	0.3049
Basal area with topkill (n=102)	0.2559	-0.0078	0.3232
Basal area in mortality (n=102)	0.1657	0.0056	0.2296

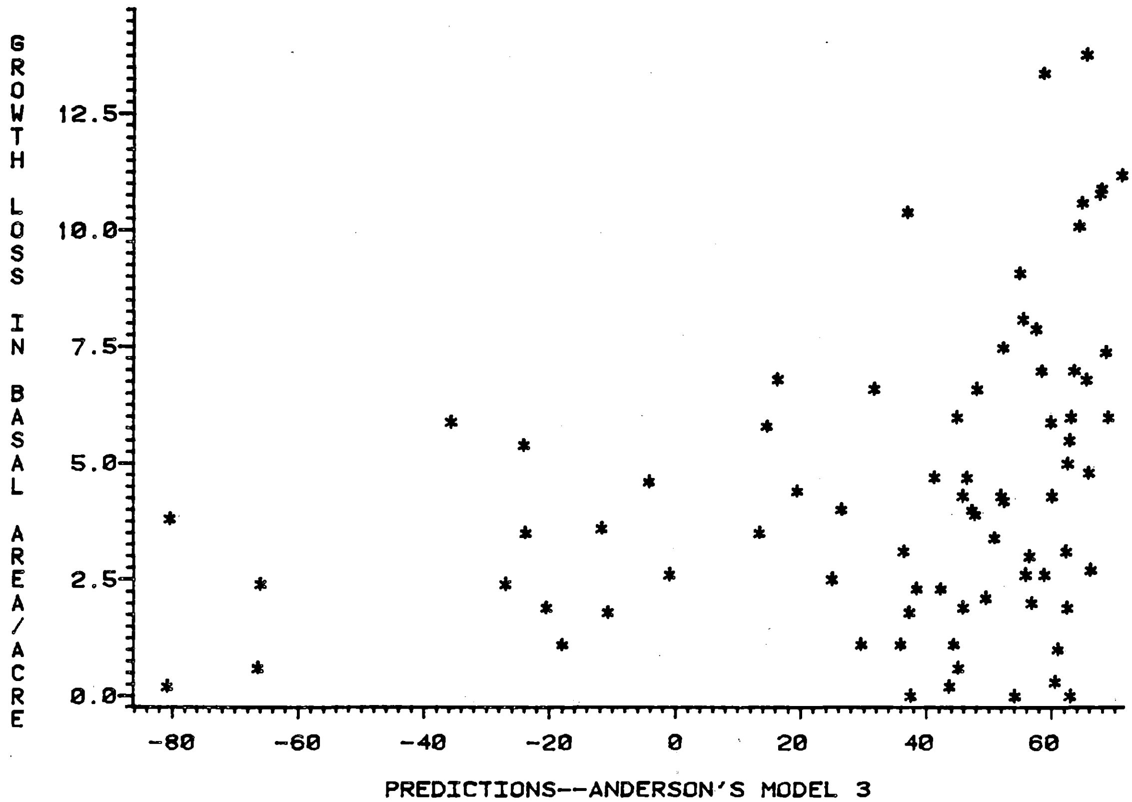


Figure 9. Relation of square feet basal area per acre growth loss to predicted WBW defoliation level obtained from Anderson's model 3 for each stand (n = 77).

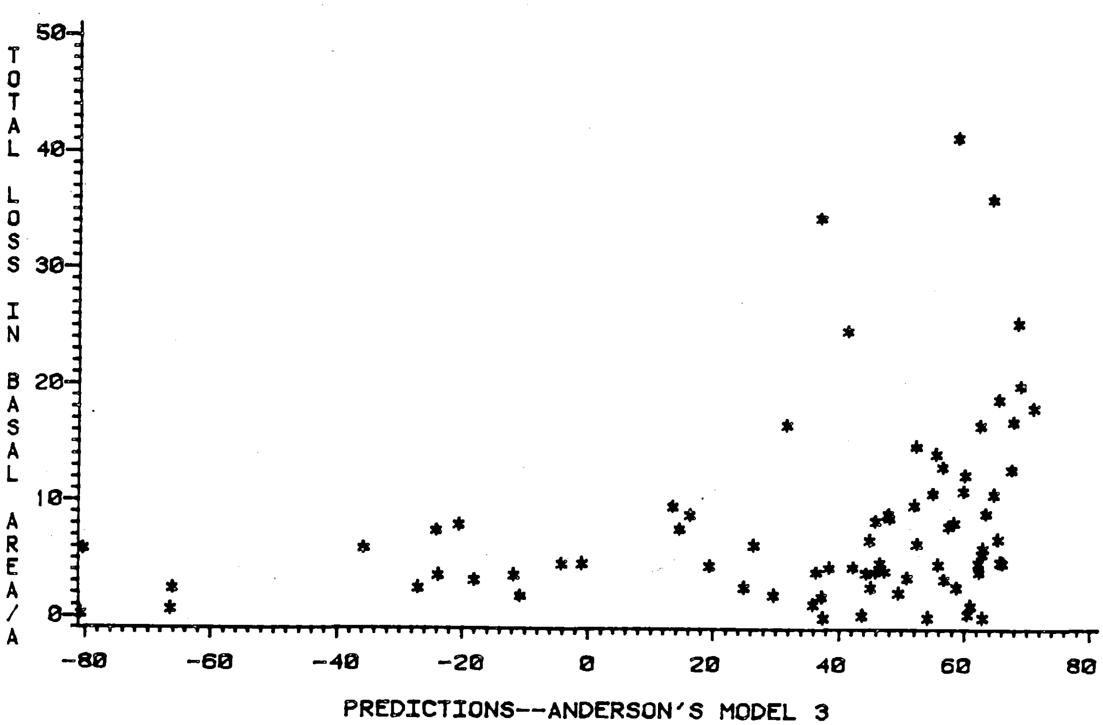


Figure 10. Relation of square feet basal area per acre total loss (growth loss and mortality) to predicted WBW defoliation level obtained from Anderson's model 3 for each stand (n = 77).

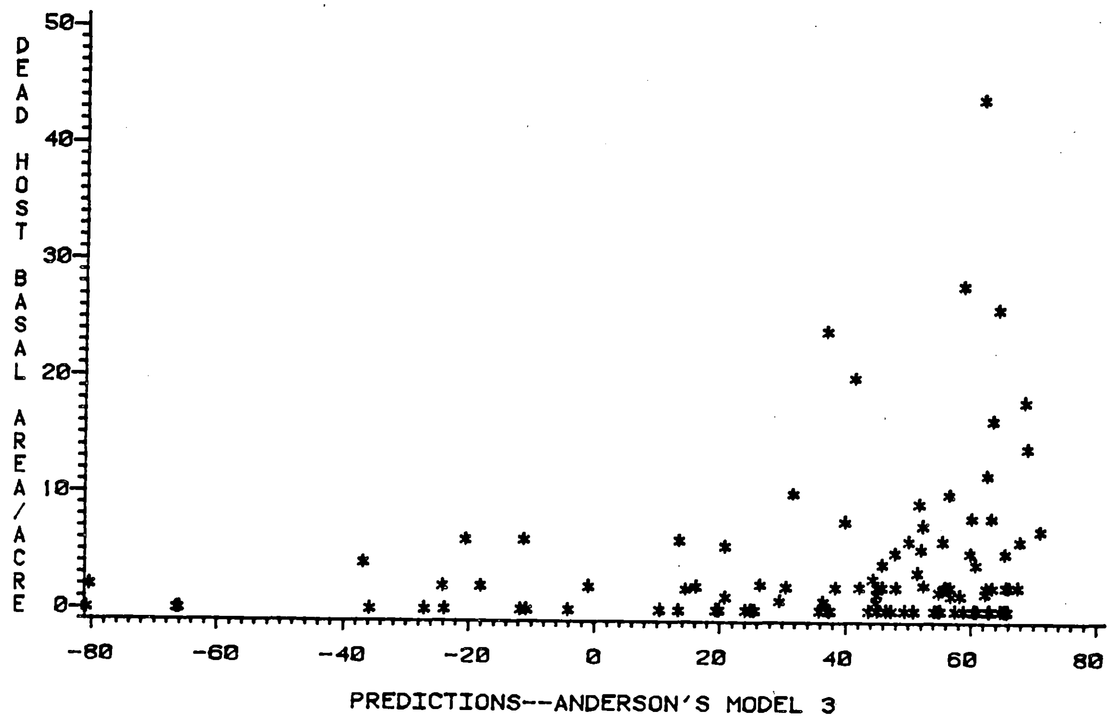


Figure 11. Relation of square feet basal area per acre in mortality to predicted WBW defoliation level obtained from Anderson's model 3 for each stand (n = 102).

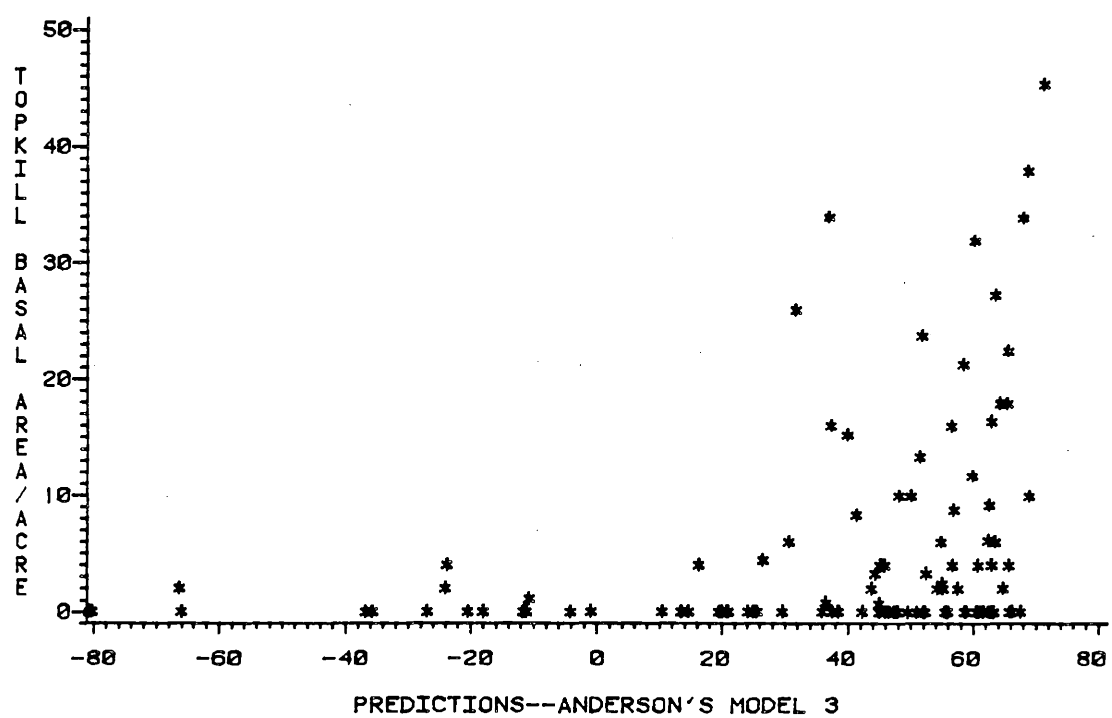


Figure 12. Relation of square feet basal area per acre of trees with topkill to predicted WBW defoliation level obtained from Anderson's model 3 for each stand (n = 102).

Discussion

The apparent success of the individual tree approach to impact calculation used in this study has several implications. Recall that in order to use this method we must assume that, aside from decreases due to WSBW-caused damage, tree growth continues at a reasonably steady rate. Thus, if some other factor such as weather were to cause growth to deviate appreciably from the steady level, this influence could not be separated from an influence associated with WSBW damage. In this regard a major advantage of the analysis of covariance method used in the original treatment of the impact data is that that method would adjust growth trees of host species for any influences that also affected nonhost species; thus, presumably, the influence of weather and other such factors common to all species would be removed. On the other hand, if WSBW-caused damage to host trees can act as a releasing agent for growth of nonhost trees (i.e. Kleinschmidt _et al_ 1980), use of covariance analysis could lead to overestimation of impacts caused by WSBW-induced damage as the difference between host and non-host growth would also include the increase in non-host growth due to release.

Nichols (personal communication), also using an individual tree approach to calculate impacts, found that non-host trees from the same area did experience some growth reduction in the 1971 to 1980 time period. He attributed this reduction to poor weather conditions. However, in this study the difference between actual and expected growth for nonhost trees as calculated by the individual tree approach was essentially zero. This indicates one of two possibilities: (1) neither weather nor release phenomena caused tree growth to deviate from normal by any significant amount or (2) the influence of weather and release cancelled each other.

Thus the risk associated with making the assumptions necessary for the individual tree approach seem small compared with the large benefits derived from stand-specific growth impact rates.

Despite the good results obtained from individual tree analysis, stand growth impact values must be viewed with caution. Although the outbreak in the area under study was declining in 1980, WBW defoliation was noted on aerial survey in 1980 and 1981. In fact, on the Okanogan National Forest the area with visible WBW defoliation increased from 1982 to 1983 (Kucera and Taylor 1984). Thus the impacts reported here reflect only that damage that took place from the start of the outbreak in 1971 to 1980 when the data was collected. Even in those stands which did not experience further defoliation, determination of the full impact of the outbreak was likely not accomplished due to incomplete coverage of the recovery period. In a Douglas-fir stand in British Columbia each of four outbreaks was followed by a recovery period of 3 to 5 years during which tree growth rates returned to normal (Alfaro et al 1982).

Therefore, the growth impacts reported here should be viewed as conservative estimates of what would result from a complete outbreak episode, at least for stands suffering repeated defoliation. Due to the stratification criteria most such stands sampled came from stratum 2; over half the stands had five or more years of defoliation visible from the air. Spraying for budworm control increased the conservative nature of the impact estimates in this strata by terminating the budworm population before the outbreak had run its natural course. In stratum 3 the median number of years of visible defoliation was only 2; thus calculated impacts are more likely to estimate the total effect of the outbreak on the stands in this stratum.

Average impact over all stands was calculated as a simple mean of the stands in strata 2 and 3. The proper calculation would have weighted each

stratum mean by the amount of acreage in that stratum, but this information was not available. This overall mean also does not include any information for stands in stratum 1. As the latter stratum was intended to include only stands that did not suffer WBW defoliation, one would be tempted to assume no growth impact in those stands and adjust the overall average downward to reflect the influence of these stands. However, due to problems in map compilation and stand location during initial stand selection, many of the stands in stratum 1 were defoliated. Median number of years of visible defoliation for the stratum was 4, more than experienced by stratum 3. This is reflected in top-kill and mortality rates which are intermediate to strata 2 and 3, rather than essentially zero.

Thus those interested in average growth impact rates should probably concentrate attention on the strata means, rather than the overall mean. Means of stratum 2 can be viewed as impacts expected in stands suffering consistent defoliation while values for stratum 3 represent stands suffering occasional defoliation.

Similar considerations apply to average top-kill and mortality rates. Here the overall means do include stands from all three strata. However, due to the lack of clarity of definition on stratum 1 and the absence of any strata weights, what population these overall means represent is unclear. Strata means, particularly those for stratum 2, do retain meaning and should be useful as representative values for stands undergoing budworm defoliation of various duration.

These problems with proper definitions of populations being estimated and period of impact being measured also apply to the vulnerability models developed in this study, but the influence does not seem to be too large. Because of lack of sampling weight information, unweighted regression was used to develop the models. This is equivalent to assuming that the stands

came from a simple random sample. The impacts being predicted correspond to the conditions measured; thus they represent damage likely to occur in a similar ten year period, rather than the damage resulting from the complete outbreak episode. Amelioration of losses resulting from budworm population control with chemicals in heavily defoliated stands is also built into these predictions. Thus predicted values should be viewed as conservative estimates. If one is only interested in relative vulnerability of the stands, the ranking of the stands on a vulnerability scale should be little affected by any additional damage not measured in this study.

Despite the problems of obtaining proper estimates, top-kill and mortality impact levels found in this survey are similar to those found by others. As shown in Table 20 percentage of host trees exhibiting top-kill in this study ranged up to 64 percent with an average of 8 percent. This is fairly similar to top-kill rates found on defoliated Douglas-fir in British Columbia where values ranged up to 63 percent with an average of 16 percent affected (Fiddick and Van Sickle 1979). In a mixed stand containing Douglas-fir, grand fir and subalpine fir in Idaho, top-kill occurred on 12.9 percent of the host trees (Bousfield et al 1975). Mortality of host trees per acre in this study averaged 3.6 percent but ranged up to 33.8 percent. In Idaho 2.1 percent of host trees died after 9 years of variable defoliation (Bousfield et al 1975). In British Columbia after up to 7 years of defoliation Douglas-fir mortality was generally less than 1 percent but reached up to 53 percent in certain stands (Collis and Van Sickle 1979).

Two trends are apparent: average top-kill and mortality impact rates are fairly light; but impacts can occasionally be quite severe. This indicates that impact tends to be clustered in a few stands. Of the trees suffering top-kill in this study, all were located in only 49 percent of the stands sampled and over half of the total of the per acre loss was

located in only 9 stands, 8.8 percent of those sampled. The distribution of mortality was similar; all dead trees occurred in 62.7 percent of the stands and over half of the total per acre mortality was in only 8 stands, 7.8 percent of those sampled.

When considering this data one should keep in mind how the information was collected. As mentioned previously, the stands sampled were not a random sample of the outbreak area; rather, they represented three distinct strata chosen to reflect differences in budworm defoliation duration. Thus one would expect higher impact rates in stratum 2 where visible heavy defoliation led to eventual chemical treatment of the stands for budworm control. As was seen in Tables 3 and 4, stands in stratum 2 did suffer higher top-kill and mortality rates than stands in the other strata. Because of this difference among strata, a weighted average of the strata means should have been calculated for the overall average; this was not possible due to lack of information on strata weights.

However the pattern of most impact confined to a few stands was true across individual strata as well. One might have expected stratum 2 to show less concentration of impact than the other strata, but this was not the case. In stratum 2 all top-killed trees occurred in only 51.3 percent of the stands and over half of the total per acre losses was located in 15.4 percent of the stands; similar figures for dead trees were 71.8 percent and 7.7 percent of the stands sampled.

This concentration of impact in a few stands would make one optimistic about the possibilities of developing good impact vulnerability models. However, two further criteria must be met: stands with similar impact levels must be similar in some other characteristics and these characteristics must have been measured in this study. Vulnerability models for top-kill and mortality developed in this study have only limited success

in explaining where impacts occurred.

The relationships built into mortality models indicate that the pattern of mortality is related to the pattern of stand species composition. Amount of host in the stand and proportion of that host in true fir species did a reasonable job in discriminating between stands with and without mortality; probability of mortality occurrence increases as both the amount of host and proportion of true fir increase. Intensity of mortality follows a similar trend; however, the amount of unexplained variation is quite large. The association is obvious--heavy mortality occurs only where large amounts of the most vulnerable species exist. Heavier mortality also tended to occur on northerly aspects; interpretation of this relationship is unclear.

The top-kill models, while more successful in fitting the data than the mortality models, are more complicated, less consistent in the relationships involved, and more difficult to interpret. There are again indications that high top-kill rates are found in stands containing large amounts of host, particularly true firs. Additional trends indicate higher impact on steep slopes, on northwesterly aspects, and in stands with large diameter trees. The most consistent trend shows that stands of moderate productivity (as measured by height/age for selected trees) are prone to higher top-kill rates than stands of low or high productivity. Having neither any personal experience with these stands nor any information on environmental differences among the stands, I am unwilling to suggest interpretations of the above trends.

Growth loss estimates also tend to agree with values found by other investigators. The similarity between individual tree losses in this study and the work by Nichols was discussed in the previous section. Average loss estimates are also similar. Growth loss, as shown in Table 7, averaged 4.5 square feet per acre in basal area over the stands in strata 2 and 3. This

corresponds to a reduction in total basal area of 4.6 percent for the ten year outbreak period. In British Columbia on Douglas-fir Alfaro and others (1982) found a basal area reduction of 22 percent resulting from four outbreak episodes, an impact quite similar to that found in this study.

Clustering of growth loss was less pronounced than for top-kill and mortality. Only 4 percent of the 77 stands sampled did not suffer any reduction in growth. There was some concentration of heavy losses; over half the total per acre basal area growth loss was contained in 26 percent of the stands. This pattern was similar for both the strata sampled. In stratum 2 all stands suffered some growth loss and 92 percent suffered losses in stratum 3. Figures for the percentage of stands containing over half of the total per acre basal area loss were 30.8 and 23.7 for strata 2 and 3, respectively.

Vulnerability models for growth loss, while leaving a great deal of variation unexplained, did have two nice properties: 1) the relationships found to be significant were consistent for all the growth loss variables and 2) these relationships agree with trends found by other investigators. All models indicate that heavy absolute growth loss is to be expected in stands with a large host component, in stands where most of the host is true fir, in stands close to 3700 feet in elevation, and in stands fairly uniform in overstory tree size. Growth loss per unit of host follows the same trends with the exception that relative loss does not vary with total amount of host in any discernable fashion.

The trends with host and true fir density parallel results found by a number of investigators (Carlson et al 1983, Fauss and Pierce 1969, Heller et al 1981, Stoszek and Mika 1983, Ulliman and Kessler 1983). Most of these other studies examined stand susceptibility as indexed by presence of visible defoliation or amount of defoliation, rather than vulnerability.

Thus variables found to be significant in these studies should be associated only with factors influencing the budworm population level or defoliation intensity. They may not be associated with those processes that determine the amount of tree growth reduction resulting from a given population level, the latter being a component of vulnerability.

The other trends portrayed in the models were also found by other investigators. The relationship of growth loss to variation in tree size is similar to that found by Stoszek and Mika (1983) for budworm defoliation and variation in tree age on the Clearwater National Forest in Idaho. The relationship with elevation is identical to that found by Anderson (1981) for the area around Twisp, Washington. As was shown in the previous section, predictions obtained from Anderson's models showed a fair degree of correlation with growth losses measured in this study.

The similarity of the vulnerability models to existing models for stand susceptibility and the lack of any new trends brings to mind a number of possible explanations. Perhaps the expression of growth loss is primarily determined by the amount of defoliation. Factors such as tree precondition may influence growth loss in only a minor fashion. This, however, seems rather unlikely.

Another possibility is that insect numbers and resistance to defoliation follow similar patterns. It may be that true firs, in addition to incurring greater levels of defoliation than Douglas-fir, are also less able to resist defoliation. Many investigators have proposed that stands under stress are more susceptible to budworm defoliation; it also seems likely that a given level of defoliation in such a stand would result in more damage than in a stand not under stress.

Finally, it is possible that while strong associations do exist between the condition of the stand and the damage resulting from a given

budworm population or defoliation level, these associations were not examined in this study. We can at least be confident that stand susceptibility and vulnerability are closely related; the fair degree of correlation between years of visible defoliation on the aerial surveys and stand damage levels gives further evidence of this.

Work Remaining

All objectives originally envisioned have been accomplished. However, as is usually the case, possibilities exist for alternate ways of analysis.

Mortality could have been examined in a different fashion. Within stands mortality tended to be clumped with most mortality only occurring on a few of the plots. Thus one could compare plot mortality to other plot attributes as was done on a stand basis in this study. Some attention to the nature of the error structure would be needed as plots are not independent.

Investigation of the utility of aerial survey ratings in the stand vulnerability models might prove interesting. Inclusion might explain differences among stands resulting from varying WBW population levels, thereby adjusting stands to a common infestation level. Significant stand attributes could then be interpreted as factors controlling the translation of defoliation into growth reduction, top-kill and mortality.

Cooperation

Obviously the very existence of this study is dependent on the data furnished by FPM in Region 6. Tommy Gregg has been particulary helpful by providing access to the raw data, explaining many of the assumptions made in conducting the original survey and documenting the algorithms used to calculate impacts in the original study.

Tom Nichols of the University of Washington has also been very helpful, providing me with a breakdown by area of budworm impact rates on the trees that he studied. This data provided the basis for the comparison of impact rates presented in the results section.

Literature Cited

Aitchison, J. and J.A.C. Brown. 1957. The lognormal distribution. Cambridge University Press, London. 176 p.

Alfaro, R.I., G.A. Van Sickle, A.J. Thomson, and E. Wegwitz. 1982. Tree mortality and radial growth losses caused by the western spruce budworm in a Douglas-fir stand in British Columbia. Can. J. For. Res. 12:780-787.

Anderson, H.N. 1981. Photo interpretation techniques establish hazard rating criteria for western spruce budworm susceptible forest stands. M.S. Thesis. University of Idaho, Moscow. 54 p.

Beauchamp, J.J. and J.S. Olson. 1973. Corrections for bias in regression estimates after logarithmic transformation. Ecology 54(6):1403-1407.

Bousfield, W.E., P.W. Underwood and R.C. Lood. 1975. Western spruce budworm impact evaluation, Yoosa Creek, Clearwater National Forest, Idaho--1974. Report No. 75-20. USDA Forest Service, Northern Region, State and Private Forestry, Missoula, MT. 9 p.

Bradu, D. and Y. Mundlak. 1970. Estimation in lognormal linear models. J. Amer. Stat. Assoc. 65(329):198-211.

Carlson, C.E., D.G. Fellin and W.C. Schmidt. 1983. The western spruce budworm in northern Rocky Mountain forests: A review of ecology, past insecticidal treatments, and silvicultural practices. pp. 76-103. In: Proceedings of symposium on management of second-growth forests. School of Forestry, University of Montana, Missoula.

Carolin, V.M. and W.K. Coulter. 1975. Comparison of western spruce budworm populations and damage on grand fir and Douglas-fir trees. USDA For. Serv. Res. Pap. PNW-195. Pac. NW For. and Range Exp. Sta., Portland, OR.

Collis, D.G. and G.A. Van Sickle. 1978. Damage appraisal cruises in spruce budworm defoliated stands of Douglas-fir in 1977. Pest Report BC-P-19. Canadian Forestry Service, Victoria, B.C. 8 p.

Daubenmire, R.F. and J.B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Tech. Bull. 60. Washington Agricultural Experiment Station, Washington State University, Pullman. 140 p.

Fauss, D.L. and W.R. Pierce. 1969. Stand conditions and spruce budworm damage in a western Montana forest. J. For. 67(5):322-325.

Fellin, D.G., R.C. Shearer and C.E. Carlson. 1983. Western spruce budworm in the northern Rocky Mountains. Western Wildlands 9(1):2-7.

Fiddick, R.L. and G.A. Van Sickle. 1979. Forest insect and disease conditions. Information Report BC-X-200. Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C. 20 p.

Harvey, Robert D., Jr. 1982. Loss assessment: western spruce budworm infestation on the Okanogan and Wenatchee National Forests. Evaluation Report USDA Forest Service, R6-FPM. 36 p.

Heller, R.C., J.J. Ulliman and H.N. Anderson. 1981. The use of photo interpretation and remote sensing techniques to establish hazard rating criteria for spruce budworm susceptible stands. Final Report. CANUSA Spruce Budworms Program--West, Portland, OR. 48 p.

Kleinschmidt, S., G.L. Baskerville and D. Solomon. 1980. Reduction of volume increment in fir-spruce stands due to defoliation by spruce budworm. Research Paper, Faculty of Forestry, Univ. of New Brunswick, Fredericton, N.B.

Kucera, D.R. and R.G. Taylor. 1984. Spruce budworm situation in North America. 1983. Misc. Pub. No. 1441. CANUSA Spruce Budworms Program--West, Portland, OR. 27 p.

Mika, P.G. and D. Twardus. 1983. Western spruce budworm impact assessment: Hazard model validation and vulnerability model development. Progress Report. CANUSA Spruce Budworms Program--West, Portland, OR. 39 p.

Olson, J.R. 1980. Individual tree analysis: a means of assessing response to nitrogen fertilizer in natural and thinned stands of western hemlock. Ph.D. Thesis. University of Washington, Seattle, WA. 150 p.

Scott, D.R.M. and T. Nichols. 1983. Growth impacts on host trees due to western spruce budworm defoliation on the east slope of the Washington Cascades. Final Report. CANUSA Spruce Budworms Program--West, Portland, OR. 71 p.

Stage, A.R. 1976. An expression for the effect of aspect, slope, and habitat type on tree growth. For. Sci. 22:457-460.

Stoszek, K.J. and P.G. Mika. 1983. The relationships of western spruce budworm outbreaks to site/stand attributes, development and management history: model completion and comparison. Final Report. CANUSA Spruce Budworms Program--West, Portland, OR. 70 p.

Stoszek, K.J., P.G. Mika, D. St. Amand and R.N. Nalley. 1981. The relationships of western spruce budworm outbreaks to site/stand attributes, development and management history: the Clearwater National Forest in Idaho. Final Report. CANUSA Spruce Budworms Program--West, Portland, OR.

Thomson, A.J. and G.A. Van Sickle. 1980. Estimation of tree growth losses caused by pest activity. Can. J. For. Res. 10(2):176-182.

Ulliman, J.J. and B.L. Kessler. 1983. Validation of a spruce budworm aerial photo/risk model. Final Report. CANUSA Spruce Budworms Program--West, Portland, OR. 87 p.

Williams, C.B., Jr., P.J. Shea and G.S. Walton. 1971. Population density of western spruce budworm as related to stand characteristics in the Bitterroot National Forest. USDA For. Serv. Res. Pap. PSW-72. Pac. SW For. and Range Exp. Sta., Berkeley, CA.

APPENDIX

Table A. Top-kill Rates in Trees per Acre by Species, Stand and Stratum.

Rates for Stratum 1

STAND	LIVE TREES PER ACRE				TOP-KILLED TREES PER ACRE				PERCENTAGE OF LIVE TREES TOP-KILLED			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
1	78.9	0.0	0.0	78.9	0.0	.	.	0.0	0.0	.	.	0.0
2	28.8	0.0	0.0	28.8	0.0	.	.	0.0	0.0	.	.	0.0
6	96.4	0.2	0.0	96.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
7	31.0	0.0	128.0	159.0	0.0	.	10.9	10.9	0.0	.	8.5	6.9
8	214.5	0.0	45.8	260.4	0.0	.	0.0	0.0	0.0	.	0.0	0.0
9	79.1	0.0	0.0	79.1	6.6	.	.	6.6	8.3	.	.	8.3
10	20.5	0.0	0.0	20.5	0.0	.	.	0.0	0.0	.	.	0.0
11	2.5	0.0	3.4	5.9	0.0	.	0.0	0.0	0.0	.	0.0	0.0
12	91.0	0.0	22.6	113.6	17.0	.	0.0	17.0	18.7	.	0.0	15.0
13	76.1	0.0	0.0	76.1	0.0	.	.	0.0	0.0	.	.	0.0
14	62.0	0.0	0.0	62.0	0.0	.	.	0.0	0.0	.	.	0.0
17	214.8	0.0	0.0	214.8	0.0	.	.	0.0	0.0	.	.	0.0
19	141.7	0.0	0.0	141.7	0.0	.	.	0.0	0.0	.	.	0.0
58	45.9	56.5	0.0	102.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
59	162.5	0.0	7.7	170.2	14.6	.	7.7	22.3	9.0	.	100.0	13.1
60	138.1	41.2	0.0	179.3	0.0	0.0	.	0.0	0.0	0.0	.	0.0
61	153.5	32.8	0.0	186.3	38.6	14.2	.	52.8	25.1	43.3	.	28.3
62	76.2	274.2	0.0	350.5	4.1	31.7	.	35.7	5.3	11.6	.	10.2
63	47.2	90.3	0.0	137.5	2.7	23.8	.	26.5	5.8	26.4	.	19.3
64	89.8	14.8	0.0	104.7	1.1	0.0	.	1.1	1.2	0.0	.	1.0
65	117.1	5.4	0.0	122.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
66	95.6	150.4	0.0	246.0	0.6	29.8	.	30.4	0.7	19.8	.	12.4
67	220.5	105.9	0.0	326.3	46.9	34.4	.	81.3	21.3	32.5	.	24.9
68	14.0	1.3	0.0	15.4	0.9	0.0	.	0.9	6.6	0.0	.	6.0
69	79.6	29.9	0.0	109.6	0.8	2.3	.	3.1	1.0	7.6	.	2.8
				AVERAGE:	5.4	11.3	3.7	11.5	4.1	11.8	21.7	5.9
				SAMPLE SIZE:	25	12	5	25	25	12	5	25

Table A. (Continued)

Rates for Stratum 2

STAND	LIVE TREES PER ACRE				TOP-KILLED TREES PER ACRE				PERCENTAGE OF LIVE TREES TOP-KILLED			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	91.0	73.3	44.4	208.7	5.2	0.0	0.0	5.2	5.7	0.0	0.0	2.5
21	69.5	0.0	14.6	84.2	39.4	.	14.6	54.0	56.6	.	100.0	64.2
22	124.9	79.8	0.0	204.8	3.6	0.0	.	3.6	2.9	0.0	.	1.8
23	85.5	64.8	0.0	150.3	0.0	0.0	.	0.0	0.0	0.0	.	0.0
24	140.9	5.5	0.0	146.5	27.9	0.0	.	27.9	19.8	0.0	.	19.1
25	125.0	54.9	0.0	179.9	39.2	0.0	.	39.2	31.4	0.0	.	21.8
26	51.7	131.4	0.0	183.1	0.0	21.3	.	21.3	0.0	16.2	.	11.6
27	38.3	65.2	0.0	103.6	0.0	33.9	.	33.9	0.0	52.0	.	32.8
28	18.9	163.3	0.0	182.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
29	20.2	143.8	0.0	164.0	11.8	30.3	.	42.0	58.2	21.1	.	25.6
30	52.4	0.0	0.0	52.4	9.6	.	.	9.6	18.4	.	.	18.4
31	107.3	9.9	0.0	117.2	25.8	4.3	.	30.1	24.0	43.6	.	25.7
32	61.3	0.5	0.0	61.8	5.6	0.0	.	5.6	9.1	0.0	.	9.0
33	7.1	141.9	0.0	149.0	0.0	12.3	.	12.3	0.0	8.7	.	8.3
34	28.4	73.2	0.0	101.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
35	53.7	72.4	0.0	126.1	0.0	0.0	.	0.0	0.0	0.0	.	0.0
36	44.2	61.7	0.0	105.9	15.3	2.9	.	18.1	34.6	4.6	.	17.1
37	174.5	2.4	43.5	220.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	60.2	0.0	0.0	60.2	0.0	.	.	0.0	0.0	.	.	0.0
39	99.4	0.0	0.0	99.4	0.0	.	.	0.0	0.0	.	.	0.0
70	68.3	156.6	58.5	283.4	10.0	32.9	26.3	69.3	14.7	21.0	44.9	24.4
71	6.6	0.0	79.1	85.7	0.0	.	0.0	0.0	0.0	.	0.0	0.0
72	27.8	55.9	45.7	129.4	0.0	8.2	32.0	40.1	0.0	14.6	69.9	31.0
73	41.2	142.8	0.0	184.1	22.3	72.1	.	94.4	54.0	50.5	.	51.3
74	80.5	52.3	0.0	132.9	53.8	29.3	.	83.1	66.8	56.0	.	62.6
75	118.6	178.5	0.0	297.0	19.3	45.5	.	64.8	16.2	25.5	.	21.8
76	166.2	2.7	0.0	168.9	0.0	0.0	.	0.0	0.0	0.0	.	0.0
77	31.3	42.7	0.0	73.9	0.0	0.0	.	0.0	0.0	0.0	.	0.0
78	140.4	33.0	0.0	173.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
79	117.0	0.0	0.0	117.0	27.3	.	.	27.3	23.3	.	.	23.3
80	122.1	1.6	0.0	123.7	51.3	0.0	.	51.3	42.0	0.0	.	41.5
81	80.3	12.3	0.0	92.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
82	49.8	0.0	0.0	49.8	0.0	.	.	0.0	0.0	.	.	0.0
83	329.4	0.0	0.0	329.4	0.0	.	.	0.0	0.0	.	.	0.0
84	30.9	66.6	0.0	97.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
85	96.7	25.4	0.0	122.1	0.0	0.0	.	0.0	0.0	0.0	.	0.0
87	202.4	0.0	0.0	202.4	0.0	.	.	0.0	0.0	.	.	0.0
88	260.1	6.0	0.0	266.1	0.0	0.0	.	0.0	0.0	0.0	.	0.0
89	94.4	0.0	0.0	94.4	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	9.4	10.1	12.1	18.8	12.2	10.8	35.8	13.2
				SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table A. (Continued)

Rates for Stratum 3

STAND	LIVE TREES PER ACRE: DF	GF	SAF	TOTAL	TOP-KILLED TREES PER ACRE: DF	GF	SAF	TOTAL	PERCENTAGE OF LIVE TREES TOP-KILLED: DF	GF	SAF	TOTAL
15	101.0	0.0	0.0	101.0	0.0	.	.	0.0	0.0	.	.	0.0
16	125.3	0.0	0.0	125.3	0.0	.	.	0.0	0.0	.	.	0.0
18	183.6	0.0	0.0	183.6	0.3	.	.	0.3	0.2	.	.	0.2
40	75.5	10.2	0.0	85.7	2.3	0.0	.	2.3	3.0	0.0	.	2.7
41	137.1	32.7	0.0	169.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
42	65.1	0.0	8.6	73.7	4.4	.	0.0	4.4	6.8	.	0.0	6.0
43	90.8	1.7	0.0	92.5	35.9	1.7	.	37.6	39.5	100.0	.	40.7
45	54.5	0.0	0.0	54.5	0.0	.	.	0.0	0.0	.	.	0.0
48	41.5	0.0	0.0	41.5	2.0	.	.	2.0	4.9	.	.	4.9
49	71.6	0.0	0.0	71.6	5.3	.	.	5.3	7.5	.	.	7.5
50	175.8	0.0	0.0	175.8	26.2	.	.	26.2	14.9	.	.	14.9
51	109.1	0.0	0.0	109.1	7.3	.	.	7.3	6.7	.	.	6.7
52	110.9	0.0	0.0	110.9	0.0	.	.	0.0	0.0	.	.	0.0
53	53.6	0.0	0.0	53.6	0.0	.	.	0.0	0.0	.	.	0.0
54	67.1	0.0	0.0	67.1	0.0	.	.	0.0	0.0	.	.	0.0
55	147.8	0.0	0.0	147.8	29.3	.	.	29.3	19.8	.	.	19.8
56	27.5	0.0	0.0	27.5	6.0	.	.	6.0	21.9	.	.	21.9
57	112.2	0.0	0.0	112.2	5.9	.	.	5.9	5.2	.	.	5.2
90	183.5	33.1	0.0	216.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
91	13.7	67.9	0.0	81.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
92	120.0	31.8	0.0	151.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
93	116.2	31.3	0.0	147.6	0.0	2.5	.	2.5	0.0	7.9	.	1.7
94	126.1	83.3	0.0	209.4	2.3	5.9	.	8.2	1.8	7.1	.	3.9
95	113.4	44.1	0.0	157.5	0.4	0.0	.	0.4	0.3	0.0	.	0.2
96	234.3	34.3	0.0	268.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
97	189.4	6.4	0.0	195.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
98	104.0	0.0	0.0	104.0	0.0	.	.	0.0	0.0	.	.	0.0
99	161.1	0.0	0.0	161.1	0.0	.	.	0.0	0.0	.	.	0.0
100	35.7	30.0	0.0	65.7	2.3	8.6	.	10.8	6.3	28.6	.	16.5
101	339.8	60.7	0.0	400.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
102	175.5	0.0	0.0	175.5	0.0	.	.	0.0	0.0	.	.	0.0
103	372.8	0.0	0.0	372.8	0.0	.	.	0.0	0.0	.	.	0.0
104	564.9	0.0	0.0	564.9	0.0	.	.	0.0	0.0	.	.	0.0
105	190.1	0.0	0.0	190.1	1.0	.	.	1.0	0.5	.	.	0.5
106	146.0	0.0	0.0	146.0	0.0	.	.	0.0	0.0	.	.	0.0
107	106.8	3.8	0.0	110.6	1.8	0.0	.	1.8	1.6	0.0	.	1.6
108	167.0	0.0	0.0	167.0	9.2	.	.	9.2	5.5	.	.	5.5
109	88.0	0.0	0.0	88.0	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	3.7	1.3	0.0	4.2	3.9	10.3	0.0	4.2
				SAMPLE SIZE:	38	14	1	38	38	14	1	38
				OVERALL AVERAGE:	6.3	8.1	7.6	11.6	7.1	10.9	26.9	8.0
				SAMPLE SIZE:	102	55	12	102	102	55	12	102

Table B. Basal Area (Square Feet) per Acre of Trees Suffering Top-kill, Broken Down by Species, Stand and Stratum.

Rates for Stratum 1

	LIVE BASAL AREA PER ACRE				TOP-KILLED BASAL AREA PER ACRE				PERCENTAGE OF BASAL AREA TOP-KILLED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
1	71.1	0.0	0.0	71.1	0.0	.	.	0.0	0.0	.	.	0.0
2	16.0	0.0	0.0	16.0	0.0	.	.	0.0	0.0	.	.	0.0
6	110.7	0.7	0.0	111.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
7	38.0	0.0	48.0	86.0	0.0	.	2.0	2.0	0.0	.	4.1	2.3
8	176.0	0.0	28.0	204.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
9	74.0	0.0	0.0	74.0	4.0	.	.	4.0	5.4	.	.	5.4
10	22.0	0.0	0.0	22.0	0.0	.	.	0.0	0.0	.	.	0.0
11	12.0	0.0	2.0	14.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
12	56.0	0.0	12.0	68.0	6.0	.	0.0	6.0	10.7	.	0.0	8.8
13	65.5	0.0	0.0	65.5	0.0	.	.	0.0	0.0	.	.	0.0
14	60.0	0.0	0.0	60.0	0.0	.	.	0.0	0.0	.	.	0.0
17	104.0	0.0	0.0	104.0	0.0	.	.	0.0	0.0	.	.	0.0
19	80.0	0.0	0.0	80.0	0.0	.	.	0.0	0.0	.	.	0.0
58	50.0	42.0	0.0	92.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
59	94.0	0.0	2.0	96.0	4.0	.	2.0	6.0	4.3	.	100.0	6.3
60	172.0	20.0	0.0	192.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
61	112.3	14.6	0.0	126.9	20.0	3.8	.	23.8	17.8	26.3	.	18.8
62	100.9	125.7	0.0	226.6	3.8	11.4	.	15.2	3.8	9.1	.	6.7
63	76.0	50.0	0.0	126.0	2.0	8.0	.	10.0	2.6	16.0	.	7.9
64	98.0	8.0	0.0	106.0	4.0	0.0	.	4.0	4.1	0.0	.	3.8
65	74.6	5.4	0.0	80.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
66	58.3	51.6	0.0	110.0	3.3	10.0	.	13.3	5.7	19.4	.	12.1
67	149.1	52.7	0.0	201.8	20.0	7.3	.	27.3	13.4	13.8	.	13.5
68	36.0	6.0	0.0	42.0	4.0	0.0	.	4.0	11.1	0.0	.	9.5
69	130.7	18.0	0.0	148.7	2.7	1.3	.	4.0	2.0	7.4	.	2.7
				AVERAGE:	3.0	3.5	0.8	4.8	3.2	7.7	20.8	3.9
				SAMPLE SIZE:	25	12	5	25	25	12	5	25

Table B. (Continued)

Rates for Stratum 2

STAND	LIVE BASAL AREA PER ACRE				TOP-KILLED BASAL AREA PER ACRE				PERCENTAGE OF BASAL AREA TOP-KILLED			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	58.0	22.0	12.0	92.0	2.0	0.0	0.0	2.0	3.4	0.0	0.0	2.2
21	52.0	0.0	8.0	60.0	24.0	.	8.0	32.0	46.2	.	100.0	53.3
22	106.0	34.0	0.0	140.0	2.0	0.0	.	2.0	1.9	0.0	.	1.4
23	94.0	30.0	0.0	124.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
24	195.0	7.5	0.0	202.5	22.5	0.0	.	22.5	11.5	0.0	.	11.1
25	67.3	29.1	0.0	96.4	16.4	0.0	.	16.4	24.3	0.0	.	17.0
26	42.0	54.0	0.0	96.0	0.0	6.0	.	6.0	0.0	11.1	.	6.2
27	22.0	38.0	0.0	60.0	0.0	10.0	.	10.0	0.0	26.3	.	16.7
28	48.0	70.0	0.0	118.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
29	11.7	70.0	0.0	81.7	1.7	10.0	.	11.7	14.3	14.3	.	14.3
30	86.0	0.0	0.0	86.0	16.0	.	.	16.0	18.6	.	.	18.6
31	68.0	4.0	0.0	72.0	16.0	2.0	.	18.0	23.5	50.0	.	25.0
32	100.0	3.1	0.0	103.1	6.1	0.0	.	6.1	6.1	0.0	.	6.0
33	8.9	63.3	0.0	72.2	0.0	3.3	.	3.3	0.0	5.3	.	4.6
34	16.0	34.0	0.0	50.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
35	42.0	30.0	0.0	72.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
36	16.0	42.0	0.0	58.0	2.0	2.0	.	4.0	12.5	4.8	.	6.9
37	144.0	4.0	16.0	164.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	34.0	0.0	0.0	34.0	0.0	.	.	0.0	0.0	.	.	0.0
39	35.4	0.0	0.0	35.4	0.0	.	.	0.0	0.0	.	.	0.0
70	56.0	66.0	18.0	140.0	10.0	16.0	8.0	34.0	17.9	24.2	44.4	24.3
71	12.0	0.0	32.0	44.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
72	20.0	44.0	38.0	102.0	0.0	2.0	24.0	26.0	0.0	4.5	63.2	25.5
73	36.0	68.0	0.0	104.0	10.0	24.0	.	34.0	27.8	35.3	.	32.7
74	74.0	28.0	0.0	102.0	28.0	10.0	.	38.0	37.8	35.7	.	37.3
75	70.0	56.0	0.0	126.0	8.0	10.0	.	18.0	11.4	17.8	.	14.3
76	112.0	5.3	0.0	117.3	0.0	0.0	.	0.0	0.0	0.0	.	0.0
77	12.0	20.0	0.0	32.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
78	105.4	12.7	0.0	118.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
79	106.3	0.0	0.0	106.3	21.3	.	.	21.3	20.0	.	.	20.0
80	154.5	0.7	0.0	155.2	45.5	0.0	.	45.5	29.5	0.0	.	29.3
81	42.4	4.8	0.0	47.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
82	52.6	0.0	0.0	52.6	0.0	.	.	0.0	0.0	.	.	0.0
83	122.0	0.0	0.0	122.0	0.0	.	.	0.0	0.0	.	.	0.0
84	20.0	32.0	0.0	52.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
85	50.0	6.0	0.0	56.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
87	98.0	0.0	0.0	98.0	0.0	.	.	0.0	0.0	.	.	0.0
88	124.0	2.0	0.0	126.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
89	36.0	0.0	0.0	36.0	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	5.9	3.3	6.7	9.4	7.9	7.9	34.6	9.4
				SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table B. (Continued)

Rates for Stratum 3

	LIVE BASAL AREA PER ACRE				TOP-KILLED BASAL AREA PER ACRE				PERCENTAGE OF BASAL AREA TOP-KILLED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
15	64.0	0.0	0.0	64.0	0.0	.	.	0.0	0.0	.	.	0.0
16	80.0	0.0	0.0	80.0	0.0	.	.	0.0	0.0	.	.	0.0
18	94.0	0.0	0.0	94.0	2.0	.	.	2.0	2.1	.	.	2.1
40	131.1	6.7	0.0	137.8	4.4	0.0	.	4.4	3.4	0.0	.	3.2
41	60.0	16.0	0.0	76.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
42	42.0	0.0	4.0	46.0	3.3	.	0.0	3.3	7.9	.	0.0	7.2
43	60.0	2.0	0.0	62.0	14.0	2.0	.	16.0	23.3	100.0	.	25.8
45	46.7	0.0	0.0	46.7	0.0	.	.	0.0	0.0	.	.	0.0
48	46.0	0.0	0.0	46.0	2.0	.	.	2.0	4.3	.	.	4.3
49	70.0	0.0	0.0	70.0	8.8	.	.	8.8	12.5	.	.	12.5
50	76.0	0.0	0.0	76.0	10.0	.	.	10.0	13.2	.	.	13.2
51	50.0	0.0	0.0	50.0	4.0	.	.	4.0	8.0	.	.	8.0
52	44.0	0.0	0.0	44.0	0.0	.	.	0.0	0.0	.	.	0.0
53	58.0	0.0	0.0	58.0	0.0	.	.	0.0	0.0	.	.	0.0
54	25.3	0.0	0.0	25.3	0.0	.	.	0.0	0.0	.	.	0.0
55	85.8	0.0	0.0	85.8	9.2	.	.	9.2	10.7	.	.	10.7
56	28.0	0.0	0.0	28.0	2.0	.	.	2.0	7.1	.	.	7.1
57	127.2	0.0	0.0	127.2	0.8	.	.	0.8	0.6	.	.	0.6
90	118.3	13.3	0.0	131.7	0.0	0.0	.	0.0	0.0	0.0	.	0.0
91	20.0	38.0	0.0	58.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
92	62.0	24.0	0.0	86.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
93	114.0	26.0	0.0	140.0	0.0	4.0	.	4.0	0.0	15.4	.	2.9
94	80.0	31.2	0.0	111.2	0.8	1.6	.	2.4	1.0	5.1	.	2.2
95	79.3	17.0	0.0	96.3	0.7	0.0	.	0.7	0.9	0.0	.	0.8
96	180.0	40.0	0.0	220.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
97	134.0	4.0	0.0	138.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
98	52.0	0.0	0.0	52.0	0.0	.	.	0.0	0.0	.	.	0.0
99	71.7	0.0	0.0	71.7	0.0	.	.	0.0	0.0	.	.	0.0
100	60.0	31.7	0.0	91.7	3.3	5.0	.	8.3	5.6	15.8	.	9.1
101	130.9	21.8	0.0	152.7	0.0	0.0	.	0.0	0.0	0.0	.	0.0
102	87.3	0.0	0.0	87.3	0.0	.	.	0.0	0.0	.	.	0.0
103	134.0	0.0	0.0	134.0	0.0	.	.	0.0	0.0	.	.	0.0
104	228.0	0.0	0.0	228.0	0.0	.	.	0.0	0.0	.	.	0.0
105	100.0	0.0	0.0	100.0	4.0	.	.	4.0	4.0	.	.	4.0
106	81.8	0.0	0.0	81.8	0.0	.	.	0.0	0.0	.	.	0.0
107	62.2	1.1	0.0	63.3	1.1	0.0	.	1.1	1.8	0.0	.	1.8
108	90.0	0.0	0.0	90.0	2.0	.	.	2.0	2.2	.	.	2.2
109	66.0	0.0	0.0	66.0	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	1.9	0.9	0.0	2.2	2.9	9.7	0.0	3.1
				SAMPLE SIZE:	38	14	1	38	38	14	1	38
				OVERALL AVERAGE:	3.7	2.7	3.7	5.6	4.9	8.3	26.0	5.7
				SAMPLE SIZE:	102	55	12	102	102	55	12	102

Table C. Mortality Rates in Trees per Acre by Species, Stand, and Stratum.

Rates for Stratum 1

	LIVE TREES PER ACRE				DEAD TREES PER ACRE				PERCENTAGE OF TOTAL TREES PER ACRE			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
1	78.9	0.0	0.0	78.9	0.0	.	.	0.0	0.0	.	.	0.0
2	28.8	0.0	0.0	28.8	0.0	.	.	0.0	0.0	.	.	0.0
6	96.4	0.2	0.0	96.6	0.4	0.0	.	0.4	0.4	0.0	.	0.4
7	31.0	0.0	128.0	159.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
8	214.5	0.0	45.8	260.4	17.0	.	0.0	17.0	7.4	.	0.0	6.1
9	79.1	0.0	0.0	79.1	0.8	.	.	0.8	1.0	.	.	1.0
10	20.5	0.0	0.0	20.5	0.0	.	.	0.0	0.0	.	.	0.0
11	2.5	0.0	3.4	5.9	0.0	.	0.0	0.0	0.0	.	0.0	0.0
12	91.0	0.0	22.6	113.6	0.0	.	0.0	0.0	0.0	.	0.0	0.0
13	76.1	0.0	0.0	76.1	1.0	.	.	1.0	1.3	.	.	1.3
14	62.0	0.0	0.0	62.0	0.0	.	.	0.0	0.0	.	.	0.0
17	214.8	0.0	0.0	214.8	7.4	.	.	7.4	3.4	.	.	3.4
19	141.7	0.0	0.0	141.7	1.5	.	.	1.5	1.1	.	.	1.1
58	45.9	56.5	0.0	102.4	0.0	14.7	.	14.7	0.0	20.6	.	12.5
59	162.5	0.0	7.7	170.2	9.2	.	0.0	9.2	5.4	.	0.0	5.1
60	138.1	41.2	0.0	179.3	4.0	0.0	.	4.0	2.8	0.0	.	2.2
61	153.5	32.8	0.0	186.3	15.7	1.1	.	16.7	9.3	3.2	.	8.2
62	76.2	274.2	0.0	350.5	1.0	12.5	.	13.5	1.4	4.3	.	3.7
63	47.2	90.3	0.0	137.5	5.4	6.8	.	12.2	10.3	7.0	.	8.2
64	89.8	14.8	0.0	104.7	13.8	0.0	.	13.8	13.3	0.0	.	11.6
65	117.1	5.4	0.0	122.4	9.3	3.6	.	12.8	7.3	39.9	.	9.5
66	95.6	150.4	0.0	246.0	0.0	9.3	.	9.3	0.0	5.8	.	3.7
67	220.5	105.9	0.0	326.3	45.7	1.3	.	47.0	17.2	1.2	.	12.6
68	14.0	1.3	0.0	15.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
69	79.6	29.9	0.0	109.6	0.7	0.6	.	1.3	0.8	2.0	.	1.2
				AVERAGE:	5.3	4.2	0.0	7.3	3.2	7.0	0.0	3.7
				SAMPLE SIZE:	25	12	5	25	25	12	5	25

Table C. (Continued)

Rates for Stratum 2

STAND	LIVE TREES PER ACRE				DEAD TREES PER ACRE				PERCENTAGE OF TOTAL TREES PER ACRE			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	91.0	73.3	44.4	208.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	69.5	0.0	14.6	84.2	5.0	.	0.0	5.0	6.7	.	0.0	5.6
22	124.9	79.8	0.0	204.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
23	85.5	64.8	0.0	150.3	7.5	0.0	.	7.5	8.0	0.0	.	4.7
24	140.9	5.5	0.0	146.5	17.1	0.0	.	17.1	10.8	0.0	.	10.4
25	125.0	54.9	0.0	179.9	0.0	0.0	.	0.0	0.0	0.0	.	0.0
26	51.7	131.4	0.0	183.1	1.6	0.0	.	1.6	2.9	0.0	.	0.9
27	38.3	65.2	0.0	103.6	0.0	1.5	.	1.5	0.0	2.3	.	1.4
28	18.9	163.3	0.0	182.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
29	20.2	143.8	0.0	164.0	1.1	0.6	.	1.7	5.3	0.4	.	1.0
30	52.4	0.0	0.0	52.4	12.3	.	.	12.3	19.0	.	.	19.0
31	107.3	9.9	0.0	117.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
32	61.3	0.5	0.0	61.8	0.5	0.0	.	0.5	0.8	0.0	.	0.8
33	7.1	141.9	0.0	149.0	2.3	3.3	.	5.7	24.7	2.3	.	3.7
34	28.4	73.2	0.0	101.5	4.1	0.0	.	4.1	12.5	0.0	.	3.8
35	53.7	72.4	0.0	126.1	0.0	0.0	.	0.0	0.0	0.0	.	0.0
36	44.2	61.7	0.0	105.9	0.7	2.9	.	3.6	1.5	4.5	.	3.3
37	174.5	2.4	43.5	220.3	1.3	0.0	0.0	1.3	0.7	0.0	0.0	0.6
38	60.2	0.0	0.0	60.2	1.0	.	.	1.0	1.6	.	.	1.6
39	99.4	0.0	0.0	99.4	0.0	.	.	0.0	0.0	.	.	0.0
70	68.3	156.6	58.5	283.4	0.5	7.3	0.0	7.8	0.7	4.5	0.0	2.7
71	6.6	0.0	79.1	85.7	0.0	.	4.8	4.8	0.0	.	5.8	5.3
72	27.8	55.9	45.7	129.4	17.1	9.6	6.9	33.5	38.1	14.6	13.1	20.6
73	41.2	142.8	0.0	184.1	24.0	51.1	.	75.1	36.8	26.3	.	29.0
74	80.5	52.3	0.0	132.9	16.2	1.9	.	18.1	16.7	3.5	.	12.0
75	118.6	178.5	0.0	297.0	71.7	14.1	.	85.8	37.7	7.3	.	22.4
76	166.2	2.7	0.0	168.9	11.1	0.0	.	11.1	6.3	0.0	.	6.2
77	31.3	42.7	0.0	73.9	0.0	0.0	.	0.0	0.0	0.0	.	0.0
78	140.4	33.0	0.0	173.5	0.0	3.0	.	3.0	0.0	8.2	.	1.7
79	117.0	0.0	0.0	117.0	2.8	.	.	2.8	2.3	.	.	2.3
80	122.1	1.6	0.0	123.7	8.6	0.0	.	8.6	6.6	0.0	.	6.5
81	80.3	12.3	0.0	92.6	2.3	0.0	.	2.3	2.8	0.0	.	2.4
82	49.8	0.0	0.0	49.8	0.0	.	.	0.0	0.0	.	.	0.0
83	329.4	0.0	0.0	329.4	1.5	.	.	1.5	0.5	.	.	0.5
84	30.9	66.6	0.0	97.5	0.0	6.0	.	6.0	0.0	8.3	.	5.8
85	96.7	25.4	0.0	122.1	0.0	1.0	.	1.0	0.0	3.9	.	0.8
87	202.4	0.0	0.0	202.4	0.0	.	.	0.0	0.0	.	.	0.0
88	260.1	6.0	0.0	266.1	1.3	0.0	.	1.3	0.5	0.0	.	0.5
89	94.4	0.0	0.0	94.4	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	5.4	3.5	2.0	8.3	6.2	3.0	3.1	4.5
				SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table C. (Continued)

Rates for Stratum 3

STAND	LIVE TREES PER ACRE DF	GF	SAF	TOTAL	DEAD TREES PER ACRE DF	GF	SAF	TOTAL	PERCENTAGE OF TOTAL TREES PER ACRE DF	GF	SAF	TOTAL
15	101.0	0.0	0.0	101.0	0.0	.	.	0.0	0.0	.	.	0.0
16	125.3	0.0	0.0	125.3	0.0	.	.	0.0	0.0	.	.	0.0
18	183.6	0.0	0.0	183.6	6.5	.	.	6.5	3.4	.	.	3.4
40	75.5	10.2	0.0	85.7	0.7	0.0	.	0.7	0.9	0.0	.	0.8
41	137.1	32.7	0.0	169.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
42	65.1	0.0	8.6	73.7	4.1	.	0.0	4.1	5.9	.	0.0	5.2
43	90.8	1.7	0.0	92.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
45	54.5	0.0	0.0	54.5	0.0	.	.	0.0	0.0	.	.	0.0
48	41.5	0.0	0.0	41.5	0.0	.	.	0.0	0.0	.	.	0.0
49	71.6	0.0	0.0	71.6	1.5	.	.	1.5	2.0	.	.	2.0
50	175.8	0.0	0.0	175.8	5.3	.	.	5.3	2.9	.	.	2.9
51	109.1	0.0	0.0	109.1	0.0	.	.	0.0	0.0	.	.	0.0
52	110.9	0.0	0.0	110.9	3.7	.	.	3.7	3.2	.	.	3.2
53	53.6	0.0	0.0	53.6	0.0	.	.	0.0	0.0	.	.	0.0
54	67.1	0.0	0.0	67.1	0.0	.	.	0.0	0.0	.	.	0.0
55	147.8	0.0	0.0	147.8	19.6	.	.	19.6	11.7	.	.	11.7
56	27.5	0.0	0.0	27.5	0.0	.	.	0.0	0.0	.	.	0.0
57	112.2	0.0	0.0	112.2	0.9	.	.	0.9	0.8	.	.	0.8
90	183.5	33.1	0.0	216.6	12.3	0.0	.	12.3	6.3	0.0	.	5.4
91	13.7	67.9	0.0	81.6	0.0	1.3	.	1.3	0.0	1.9	.	1.6
92	120.0	31.8	0.0	151.8	3.9	0.0	.	3.9	3.2	0.0	.	2.5
93	116.2	31.3	0.0	147.6	0.0	3.8	.	3.8	0.0	10.9	.	2.5
94	126.1	83.3	0.0	209.4	4.2	0.0	.	4.2	3.3	0.0	.	2.0
95	113.4	44.1	0.0	157.5	1.4	0.0	.	1.4	1.2	0.0	.	0.9
96	234.3	34.3	0.0	268.6	24.2	4.0	.	28.1	9.4	10.4	.	9.5
97	189.4	6.4	0.0	195.8	6.6	0.0	.	6.6	3.4	0.0	.	3.3
98	104.0	0.0	0.0	104.0	0.0	.	.	0.0	0.0	.	.	0.0
99	161.1	0.0	0.0	161.1	0.0	.	.	0.0	0.0	.	.	0.0
100	35.7	30.0	0.0	65.7	3.1	30.4	.	33.5	8.0	50.4	.	33.8
101	339.8	60.7	0.0	400.4	0.0	21.6	.	21.6	0.0	26.3	.	5.1
102	175.5	0.0	0.0	175.5	0.0	.	.	0.0	0.0	.	.	0.0
103	372.8	0.0	0.0	372.8	0.0	.	.	0.0	0.0	.	.	0.0
104	564.9	0.0	0.0	564.9	0.0	.	.	0.0	0.0	.	.	0.0
105	190.1	0.0	0.0	190.1	0.0	.	.	0.0	0.0	.	.	0.0
106	146.0	0.0	0.0	146.0	0.0	.	.	0.0	0.0	.	.	0.0
107	106.8	3.8	0.0	110.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
108	167.0	0.0	0.0	167.0	0.0	.	.	0.0	0.0	.	.	0.0
109	88.0	0.0	0.0	88.0	0.6	.	.	0.6	0.6	.	.	0.6
				AVERAGE:	2.6	4.4	0.0	4.2	1.7	7.1	0.0	2.6
				SAMPLE SIZE:	38	14	1	38	38	14	1	38
				OVERALL AVERAGE:	4.3	3.9	1.0	6.5	3.8	4.9	1.6	3.6
				SAMPLE SIZE:	102	55	12	102	102	55	12	102

Table D. Mortality Rates in Basal Area (Square Feet) per Acre by Species, Stand, and Stratum.

Rates for Stratum 1

STAND	LIVE BASAL AREA PER ACRE				DEAD BASAL AREA PER ACRE				PERCENT OF TOTAL BASAL AREA PER ACRE			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
1	71.1	0.0	0.0	71.1	0.0	.	.	0.0	0.0	.	.	0.0
2	16.0	0.0	0.0	16.0	0.0	.	.	0.0	0.0	.	.	0.0
6	110.7	0.7	0.0	111.4	1.4	0.0	.	1.4	1.3	0.0	.	1.3
7	38.0	0.0	48.0	86.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
8	176.0	0.0	28.0	204.0	44.0	.	0.0	44.0	20.0	.	0.0	17.7
9	74.0	0.0	0.0	74.0	2.0	.	.	2.0	2.6	.	.	2.6
10	22.0	0.0	0.0	22.0	0.0	.	.	0.0	0.0	.	.	0.0
11	12.0	0.0	2.0	14.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
12	56.0	0.0	12.0	68.0	0.0	.	0.0	0.0	0.0	.	0.0	0.0
13	65.5	0.0	0.0	65.5	1.1	.	.	1.1	1.7	.	.	1.7
14	60.0	0.0	0.0	60.0	0.0	.	.	0.0	0.0	.	.	0.0
17	104.0	0.0	0.0	104.0	4.0	.	.	4.0	3.7	.	.	3.7
19	80.0	0.0	0.0	80.0	6.0	.	.	6.0	7.0	.	.	7.0
58	50.0	42.0	0.0	92.0	0.0	2.0	.	2.0	0.0	4.5	.	2.1
59	94.0	0.0	2.0	96.0	2.0	.	0.0	2.0	2.1	.	0.0	2.0
60	172.0	20.0	0.0	192.0	8.0	0.0	.	8.0	4.4	0.0	.	4.0
61	112.3	14.6	0.0	126.9	7.7	1.5	.	9.2	6.4	9.5	.	6.8
62	100.9	125.7	0.0	226.6	1.9	5.7	.	7.6	1.8	4.4	.	3.3
63	76.0	50.0	0.0	126.0	2.0	4.0	.	6.0	2.6	7.4	.	4.5
64	98.0	8.0	0.0	106.0	4.0	0.0	.	4.0	3.9	0.0	.	3.6
65	74.6	5.4	0.0	80.0	1.8	3.6	.	5.4	2.4	40.0	.	6.4
66	58.3	51.6	0.0	110.0	0.0	3.3	.	3.3	0.0	6.1	.	2.9
67	149.1	52.7	0.0	201.8	14.5	1.8	.	16.4	8.9	3.3	.	7.5
68	36.0	6.0	0.0	42.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
69	130.7	18.0	0.0	148.7	1.3	0.7	.	2.0	1.0	3.6	.	1.3
				AVERAGE:	4.1	1.9	0.0	5.0	2.8	6.6	0.0	3.1
				SAMPLE SIZE:	25	12	5	25	25	12	5	25

Table D. (Continued)

Rates for Stratum 2

STAND	LIVE BASAL AREA PER ACRE DF	GF	SAF	TOTAL	DEAD BASAL AREA PER ACRE DF	GF	SAF	TOTAL	PERCENT OF TOTAL BASAL AREA PER ACRE DF	GF	SAF	TOTAL
20	58.0	22.0	12.0	92.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	52.0	0.0	8.0	60.0	8.0	.	0.0	8.0	13.3	.	0.0	11.8
22	106.0	34.0	0.0	140.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
23	94.0	30.0	0.0	124.0	2.0	0.0	.	2.0	2.1	0.0	.	1.6
24	195.0	7.5	0.0	202.5	5.0	0.0	.	5.0	2.5	0.0	.	2.4
25	67.3	29.1	0.0	96.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
26	42.0	54.0	0.0	96.0	2.0	0.0	.	2.0	4.5	0.0	.	2.0
27	22.0	38.0	0.0	60.0	0.0	2.0	.	2.0	0.0	5.0	.	3.2
28	48.0	70.0	0.0	118.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
29	11.7	70.0	0.0	81.7	3.3	1.7	.	5.0	22.2	2.3	.	5.8
30	86.0	0.0	0.0	86.0	10.0	.	.	10.0	10.4	.	.	10.4
31	68.0	4.0	0.0	72.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
32	100.0	3.1	0.0	103.1	1.5	0.0	.	1.5	1.5	0.0	.	1.5
33	8.9	63.3	0.0	72.2	1.1	1.1	.	2.2	11.1	1.7	.	3.0
34	16.0	34.0	0.0	50.0	2.0	0.0	.	2.0	11.1	0.0	.	3.8
35	42.0	30.0	0.0	72.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
36	16.0	42.0	0.0	58.0	2.0	2.0	.	4.0	11.1	4.5	.	6.5
37	144.0	4.0	16.0	164.0	2.0	0.0	0.0	2.0	1.4	0.0	0.0	1.2
38	34.0	0.0	0.0	34.0	2.0	.	.	2.0	5.6	.	.	5.6
39	35.4	0.0	0.0	35.4	0.0	.	.	0.0	0.0	.	.	0.0
70	56.0	66.0	18.0	140.0	2.0	4.0	0.0	6.0	3.4	5.7	0.0	4.1
71	12.0	0.0	32.0	44.0	0.0	.	2.0	2.0	0.0	.	5.9	4.3
72	20.0	44.0	38.0	102.0	4.0	4.0	2.0	10.0	16.7	8.3	5.0	8.9
73	36.0	68.0	0.0	104.0	10.0	14.0	.	24.0	21.7	17.1	.	18.8
74	74.0	28.0	0.0	102.0	16.0	2.0	.	18.0	17.8	6.7	.	15.0
75	70.0	56.0	0.0	126.0	24.0	2.0	.	26.0	25.5	3.4	.	17.1
76	112.0	5.3	0.0	117.3	5.3	0.0	.	5.3	4.5	0.0	.	4.3
77	12.0	20.0	0.0	32.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
78	105.4	12.7	0.0	118.2	0.0	1.8	.	1.8	0.0	12.5	.	1.5
79	106.3	0.0	0.0	106.3	1.3	.	.	1.3	1.2	.	.	1.2
80	154.5	0.7	0.0	155.2	6.9	0.0	.	6.9	4.3	0.0	.	4.3
81	42.4	4.8	0.0	47.2	0.8	0.0	.	0.8	1.9	0.0	.	1.7
82	52.6	0.0	0.0	52.6	0.0	.	.	0.0	0.0	.	.	0.0
83	122.0	0.0	0.0	122.0	2.0	.	.	2.0	1.6	.	.	1.6
84	20.0	32.0	0.0	52.0	0.0	2.0	.	2.0	0.0	5.9	.	3.7
85	50.0	6.0	0.0	56.0	0.0	2.0	.	2.0	0.0	25.0	.	3.4
87	98.0	0.0	0.0	98.0	0.0	.	.	0.0	0.0	.	.	0.0
88	124.0	2.0	0.0	126.0	6.0	0.0	.	6.0	4.6	0.0	.	4.5
89	36.0	0.0	0.0	36.0	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	3.1	1.3	0.7	4.2	5.1	3.4	1.8	3.9
				SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table D. (Continued)

Rates for Stratum 3

STAND	LIVE BASAL AREA PER ACRE DF	GF	SAF	TOTAL	DEAD BASAL AREA PER ACRE DF	GF	SAF	TOTAL	PERCENT OF TOTAL BASAL AREA PER ACRE DF	GF	SAF	TOTAL
15	64.0	0.0	0.0	64.0	0.0	.	.	0.0	0.0	.	.	0.0
16	80.0	0.0	0.0	80.0	0.0	.	.	0.0	0.0	.	.	0.0
18	94.0	0.0	0.0	94.0	2.0	.	.	2.0	2.1	.	.	2.1
40	131.1	6.7	0.0	137.8	2.2	0.0	.	2.2	1.7	0.0	.	1.6
41	60.0	16.0	0.0	76.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
42	42.0	0.0	4.0	46.0	2.7	.	0.0	2.7	6.0	.	0.0	5.5
43	60.0	2.0	0.0	62.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
45	46.7	0.0	0.0	46.7	0.0	.	.	0.0	0.0	.	.	0.0
48	46.0	0.0	0.0	46.0	0.0	.	.	0.0	0.0	.	.	0.0
49	70.0	0.0	0.0	70.0	1.3	.	.	1.3	1.8	.	.	1.8
50	76.0	0.0	0.0	76.0	14.0	.	.	14.0	15.6	.	.	15.6
51	50.0	0.0	0.0	50.0	0.0	.	.	0.0	0.0	.	.	0.0
52	44.0	0.0	0.0	44.0	2.0	.	.	2.0	4.3	.	.	4.3
53	58.0	0.0	0.0	58.0	0.0	.	.	0.0	0.0	.	.	0.0
54	25.3	0.0	0.0	25.3	0.0	.	.	0.0	0.0	.	.	0.0
55	85.8	0.0	0.0	85.8	11.7	.	.	11.7	12.0	.	.	12.0
56	28.0	0.0	0.0	28.0	0.0	.	.	0.0	0.0	.	.	0.0
57	127.2	0.0	0.0	127.2	0.8	.	.	0.8	0.6	.	.	0.6
90	118.3	13.3	0.0	131.7	5.0	0.0	.	5.0	4.1	0.0	.	3.7
91	20.0	38.0	0.0	58.0	0.0	2.0	.	2.0	0.0	5.0	.	3.3
92	62.0	24.0	0.0	86.0	6.0	0.0	.	6.0	8.8	0.0	.	6.5
93	114.0	26.0	0.0	140.0	0.0	2.0	.	2.0	0.0	7.1	.	1.4
94	80.0	31.2	0.0	111.2	1.6	0.0	.	1.6	2.0	0.0	.	1.4
95	79.3	17.0	0.0	96.3	0.7	0.0	.	0.7	0.9	0.0	.	0.8
96	180.0	40.0	0.0	220.0	24.0	4.0	.	28.0	11.8	9.1	.	11.3
97	134.0	4.0	0.0	138.0	6.0	0.0	.	6.0	4.3	0.0	.	4.2
98	52.0	0.0	0.0	52.0	0.0	.	.	0.0	0.0	.	.	0.0
99	71.7	0.0	0.0	71.7	0.0	.	.	0.0	0.0	.	.	0.0
100	60.0	31.7	0.0	91.7	3.3	16.7	.	20.0	5.3	34.5	.	17.9
101	130.9	21.8	0.0	152.7	0.0	7.3	.	7.3	0.0	25.0	.	4.5
102	87.3	0.0	0.0	87.3	0.0	.	.	0.0	0.0	.	.	0.0
103	134.0	0.0	0.0	134.0	0.0	.	.	0.0	0.0	.	.	0.0
104	228.0	0.0	0.0	228.0	0.0	.	.	0.0	0.0	.	.	0.0
105	100.0	0.0	0.0	100.0	0.0	.	.	0.0	0.0	.	.	0.0
106	81.8	0.0	0.0	81.8	0.0	.	.	0.0	0.0	.	.	0.0
107	62.2	1.1	0.0	63.3	0.0	0.0	.	0.0	0.0	0.0	.	0.0
108	90.0	0.0	0.0	90.0	0.0	.	.	0.0	0.0	.	.	0.0
109	66.0	0.0	0.0	66.0	2.0	.	.	2.0	2.9	.	.	2.9
				AVERAGE:	2.2	2.3	0.0	3.1	2.2	5.8	0.0	2.7
				SAMPLE SIZE:	38	14	1	38	38	14	1	38
				OVERALL AVERAGE:	3.0	1.7	0.3	4.0	3.5	4.7	0.9	3.3
				SAMPLE SIZE:	102	55	12	102	102	55	12	102

Table E. Mortality Rates in Volume (Cubic Feet) per Acre by Species, Stand, and Stratum.

Rates for Stratum 1

STAND	LIVE CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	DEAD CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	PERCENT OF TOTAL CUBIC FEET PER ACRE DF	GF	SAF	TOTAL
1	1995.2	0.0	0.0	1995.2	0.0	.	.	0.0	0.0	.	.	0.0
2	388.5	0.0	0.0	388.5	0.0	.	.	0.0	0.0	.	.	0.0
6	3377.2	25.2	0.0	3402.4	50.6	0.0	.	50.6	1.5	0.0	.	1.5
7	1210.2	0.0	911.5	2121.7	0.0	.	0.0	0.0	0.0	.	0.0	0.0
8	5262.5	0.0	681.3	5943.8	1619.1	.	0.0	1619.1	23.5	.	0.0	21.4
9	1988.4	0.0	0.0	1988.4	62.4	.	.	62.4	3.0	.	.	3.0
10	700.9	0.0	0.0	700.9	0.0	.	.	0.0	0.0	.	.	0.0
11	425.5	0.0	55.6	481.1	0.0	.	0.0	0.0	0.0	.	0.0	0.0
12	1620.9	0.0	291.0	1911.9	0.0	.	0.0	0.0	0.0	.	0.0	0.0
13	2056.2	0.0	0.0	2056.2	34.3	.	.	34.3	1.6	.	.	1.6
14	1834.1	0.0	0.0	1834.1	0.0	.	.	0.0	0.0	.	.	0.0
17	2596.9	0.0	0.0	2596.9	110.4	.	.	110.4	4.1	.	.	4.1
19	2097.3	0.0	0.0	2097.3	220.8	.	.	220.8	9.5	.	.	9.5
58	1509.5	1172.2	0.0	2681.7	0.0	0.0	.	0.0	0.0	0.0	.	0.0
59	2468.8	0.0	28.2	2497.0	20.0	.	0.0	20.0	0.8	.	0.0	0.8
60	6486.3	526.7	0.0	7013.0	327.5	0.0	.	327.5	4.8	0.0	.	4.5
61	3334.2	372.5	0.0	3706.7	198.1	53.2	.	251.3	5.6	12.5	.	6.3
62	3595.2	3180.9	0.0	6776.1	69.9	151.0	.	220.9	1.9	4.5	.	3.2
63	2525.1	1282.7	0.0	3807.8	40.0	109.2	.	149.2	1.6	7.8	.	3.8
64	3103.4	207.4	0.0	3310.8	68.6	0.0	.	68.6	2.2	0.0	.	2.0
65	2154.2	168.8	0.0	2323.0	14.4	114.3	.	128.7	0.7	40.4	.	5.2
66	1554.2	1054.8	0.0	2609.0	0.0	67.0	.	67.0	0.0	6.0	.	2.5
67	4018.2	1263.5	0.0	5281.7	258.1	57.5	.	315.6	6.0	4.4	.	5.6
68	1231.2	223.7	0.0	1454.9	0.0	0.0	.	0.0	0.0	0.0	.	0.0
69	4750.9	506.8	0.0	5257.7	49.4	21.4	.	70.8	1.0	4.1	.	1.3
				AVERAGE:	125.7	47.8	0.0	148.7	2.7	6.6	0.0	3.1
				SAMPLE SIZE:	25	12	5	25	25	12	5	25

Table E. (Continued)

Rates for Stratum 2

STAND	LIVE CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	DEAD CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	PERCENT OF TOTAL CUBIC FEET PER ACRE DF	GF	SAF	TOTAL
20	1273.7	315.0	152.6	1741.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	1457.9	0.0	174.6	1632.5	273.1	.	0.0	273.1	15.8	.	0.0	14.3
22	2921.1	660.5	0.0	3581.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
23	3261.3	768.8	0.0	4030.1	29.7	0.0	.	29.7	0.9	0.0	.	0.7
24	6221.7	235.7	0.0	6457.4	89.1	0.0	.	89.1	1.4	0.0	.	1.4
25	1466.8	627.9	0.0	2094.7	0.0	0.0	.	0.0	0.0	0.0	.	0.0
26	1188.4	1136.3	0.0	2324.7	61.1	0.0	.	61.1	4.9	0.0	.	2.6
27	555.4	956.7	0.0	1512.1	0.0	60.4	.	60.4	0.0	5.9	.	3.8
28	1802.4	1549.3	0.0	3351.7	0.0	0.0	.	0.0	0.0	0.0	.	0.0
29	279.4	1511.2	0.0	1790.6	105.4	52.3	.	157.7	27.4	3.3	.	8.1
30	2729.6	0.0	0.0	2729.6	264.1	.	.	264.1	8.8	.	.	8.8
31	1497.0	73.0	0.0	1570.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
32	3446.9	128.2	0.0	3575.1	57.7	0.0	.	57.7	1.6	0.0	.	1.6
33	277.6	1439.0	0.0	1716.6	24.3	19.5	.	43.8	8.0	1.3	.	2.5
34	387.2	691.8	0.0	1079.0	40.1	0.0	.	40.1	9.4	0.0	.	3.6
35	1137.1	635.7	0.0	1772.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
36	361.5	1065.1	0.0	1426.6	73.5	48.8	.	122.3	16.9	4.4	.	7.9
37	3368.5	103.3	274.4	3746.2	51.3	0.0	0.0	51.3	1.5	0.0	0.0	1.4
38	796.9	0.0	0.0	796.9	59.0	.	.	59.0	6.9	.	.	6.9
39	601.3	0.0	0.0	601.3	0.0	.	.	0.0	0.0	.	.	0.0
70	1647.1	1479.4	316.3	3442.8	79.6	90.9	0.0	170.5	4.6	5.8	0.0	4.7
71	303.7	0.0	520.1	823.8	0.0	.	32.7	32.7	0.0	.	5.9	3.8
72	454.6	1120.0	928.1	2502.7	39.9	72.1	27.3	139.2	8.1	6.0	2.9	5.3
73	1092.9	1630.7	0.0	2723.6	220.9	242.6	.	463.5	16.8	13.0	.	14.5
74	2398.8	788.3	0.0	3187.1	521.5	63.9	.	585.4	17.9	7.5	.	15.5
75	1756.8	979.3	0.0	2736.1	459.2	0.0	.	459.2	20.7	0.0	.	14.4
76	3219.7	191.6	0.0	3411.3	132.9	0.0	.	132.9	4.0	0.0	.	3.7
77	222.9	415.1	0.0	638.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
78	2832.7	248.9	0.0	3081.6	0.0	43.4	.	43.4	0.0	14.8	.	1.4
79	2980.2	0.0	0.0	2980.2	27.1	.	.	27.1	0.9	.	.	0.9
80	4787.3	13.9	0.0	4801.2	190.7	0.0	.	190.7	3.8	0.0	.	3.8
81	949.1	92.8	0.0	1041.9	14.1	0.0	.	14.1	1.5	0.0	.	1.3
82	1513.4	0.0	0.0	1513.4	0.0	.	.	0.0	0.0	.	.	0.0
83	2306.1	0.0	0.0	2306.1	55.2	.	.	55.2	2.3	.	.	2.3
84	529.5	698.9	0.0	1228.4	0.0	32.9	.	32.9	0.0	4.5	.	2.6
85	1085.2	67.2	0.0	1152.4	0.0	64.7	.	64.7	0.0	49.1	.	5.3
87	2277.0	0.0	0.0	2277.0	0.0	.	.	0.0	0.0	.	.	0.0
88	2853.8	36.0	0.0	2889.8	207.4	0.0	.	207.4	6.8	0.0	.	6.7
89	608.2	0.0	0.0	608.2	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	78.9	27.3	10.0	100.7	4.9	4.0	1.5	3.8
				SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table E. (Continued)

Rates for Stratum 3

STAND	LIVE CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	DEAD CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	PERCENT OF TOTAL CUBIC FEET PER ACRE DF	GF	SAF	TOTAL
15	1564.2	0.0	0.0	1564.2	0.0	.	.	0.0	0.0	.	.	0.0
16	2226.1	0.0	0.0	2226.1	0.0	.	.	0.0	0.0	.	.	0.0
18	2412.3	0.0	0.0	2412.3	33.0	.	.	33.0	1.3	.	.	1.3
40	4110.1	160.1	0.0	4270.2	75.0	0.0	.	75.0	1.8	0.0	.	1.7
41	1200.3	336.1	0.0	1536.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
42	1031.7	0.0	86.1	1117.8	65.4	.	0.0	65.4	6.0	.	0.0	5.5
43	1570.9	58.0	0.0	1628.9	0.0	0.0	.	0.0	0.0	0.0	.	0.0
45	1316.4	0.0	0.0	1316.4	0.0	.	.	0.0	0.0	.	.	0.0
48	1612.5	0.0	0.0	1612.5	0.0	.	.	0.0	0.0	.	.	0.0
49	2093.2	0.0	0.0	2093.2	34.0	.	.	34.0	1.6	.	.	1.6
50	1618.0	0.0	0.0	1618.0	439.0	.	.	439.0	21.3	.	.	21.3
51	994.1	0.0	0.0	994.1	0.0	.	.	0.0	0.0	.	.	0.0
52	897.2	0.0	0.0	897.2	45.7	.	.	45.7	4.8	.	.	4.8
53	1555.2	0.0	0.0	1555.2	0.0	.	.	0.0	0.0	.	.	0.0
54	451.5	0.0	0.0	451.5	0.0	.	.	0.0	0.0	.	.	0.0
55	2178.1	0.0	0.0	2178.1	309.3	.	.	309.3	12.4	.	.	12.4
56	732.9	0.0	0.0	732.9	0.0	.	.	0.0	0.0	.	.	0.0
57	4297.3	0.0	0.0	4297.3	22.9	.	.	22.9	0.5	.	.	0.5
90	3053.9	275.2	0.0	3329.1	102.9	0.0	.	102.9	3.3	0.0	.	3.0
91	645.5	937.7	0.0	1583.2	0.0	64.1	.	64.1	0.0	6.4	.	3.9
92	1656.9	731.2	0.0	2388.1	234.6	0.0	.	234.6	12.4	0.0	.	8.9
93	3735.3	833.4	0.0	4568.7	0.0	47.5	.	47.5	0.0	5.4	.	1.0
94	2043.6	614.5	0.0	2658.1	30.5	0.0	.	30.5	1.5	0.0	.	1.1
95	2256.4	376.7	0.0	2633.1	18.8	0.0	.	18.8	0.8	0.0	.	0.7
96	5458.6	1316.0	0.0	6774.6	771.7	127.7	.	899.4	12.4	8.8	.	11.7
97	3965.3	110.5	0.0	4075.8	184.3	0.0	.	184.3	4.4	0.0	.	4.3
98	1200.9	0.0	0.0	1200.9	0.0	.	.	0.0	0.0	.	.	0.0
99	1473.4	0.0	0.0	1473.4	0.0	.	.	0.0	0.0	.	.	0.0
100	2138.5	1015.2	0.0	3153.7	100.3	416.2	.	516.5	4.5	29.1	.	14.1
101	2718.0	423.4	0.0	3141.4	0.0	132.7	.	132.7	0.0	23.9	.	4.1
102	1967.4	0.0	0.0	1967.4	0.0	.	.	0.0	0.0	.	.	0.0
103	2579.2	0.0	0.0	2579.2	0.0	.	.	0.0	0.0	.	.	0.0
104	4956.9	0.0	0.0	4956.9	0.0	.	.	0.0	0.0	.	.	0.0
105	2449.9	0.0	0.0	2449.9	0.0	.	.	0.0	0.0	.	.	0.0
106	2072.4	0.0	0.0	2072.4	0.0	.	.	0.0	0.0	.	.	0.0
107	1532.5	18.0	0.0	1550.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
108	2180.6	0.0	0.0	2180.6	0.0	.	.	0.0	0.0	.	.	0.0
109	1565.0	0.0	0.0	1565.0	53.8	.	.	53.8	3.3	.	.	3.3
				AVERAGE:	66.3	56.3	0.0	87.1	2.4	5.3	0.0	2.8
				SAMPLE SIZE:	38	14	1	38	38	14	1	38
				OVERALL AVERAGE:	85.7	39.1	5.0	107.4	3.4	4.9	0.7	3.3
				SAMPLE SIZE:	102	55	12	102	102	55	12	102

Table F. Mortality Rates in Volume (Board Feet) per Acre by Species, Stand and Stratum.

Rates for Stratum 1

STAND	LIVE BOARD FEET PER ACRE				DEAD BOARD FEET PER ACRE				PERCENT OF TOTAL BOARD FEET PER ACRE			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
1	9664.4	0.0	0.0	9664.4	0.0	.	.	0.0	0.0	.	.	0.0
2	1584.3	0.0	0.0	1584.3	0.0	.	.	0.0	0.0	.	.	0.0
6	17551.5	150.9	0.0	17702.4	306.0	0.0	.	306.0	1.7	0.0	.	1.7
7	6117.1	0.0	2559.1	8676.2	0.0	.	0.0	0.0	0.0	.	0.0	0.0
8	25951.7	0.0	2182.3	28134.0	9471.8	.	0.0	9471.8	26.7	.	0.0	25.2
9	9666.7	0.0	0.0	9666.7	344.4	.	.	344.4	3.4	.	.	3.4
10	3631.7	0.0	0.0	3631.7	0.0	.	.	0.0	0.0	.	.	0.0
11	2623.5	0.0	119.4	2742.9	0.0	.	0.0	0.0	0.0	.	0.0	0.0
12	7709.8	0.0	805.3	8515.1	0.0	.	0.0	0.0	0.0	.	0.0	0.0
13	10085.8	0.0	0.0	10085.8	154.3	.	.	154.3	1.5	.	.	1.5
14	8949.3	0.0	0.0	8949.3	0.0	.	.	0.0	0.0	.	.	0.0
17	9539.7	0.0	0.0	9539.7	497.0	.	.	497.0	5.0	.	.	5.0
19	9233.2	0.0	0.0	9233.2	1339.5	.	.	1339.5	12.7	.	.	12.7
58	6863.4	4978.0	0.0	11841.4	0.0	0.0	.	0.0	0.0	0.0	.	0.0
59	8870.8	0.0	0.0	8870.8	0.0	.	.	0.0	0.0	.	.	0.0
60	34475.6	1461.5	0.0	35937.1	1872.4	0.0	.	1872.4	5.2	0.0	.	5.0
61	15082.7	1706.2	0.0	16788.9	863.3	274.0	.	1137.3	5.4	13.8	.	6.3
62	18356.4	11330.3	0.0	29686.7	374.8	715.9	.	1090.7	2.0	5.9	.	3.5
63	13233.0	4519.5	0.0	17752.5	0.0	431.5	.	431.5	0.0	8.7	.	2.4
64	14930.1	908.0	0.0	15838.1	286.8	0.0	.	286.8	1.9	0.0	.	1.8
65	9694.1	733.0	0.0	10427.1	0.0	510.6	.	510.6	0.0	41.1	.	4.7
66	5898.1	4055.3	0.0	9953.4	0.0	237.9	.	237.9	0.0	5.5	.	2.3
67	15484.4	4161.8	0.0	19646.2	446.8	282.6	.	729.4	2.8	6.4	.	3.6
68	7190.5	1395.5	0.0	8586.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
69	26031.6	1904.4	0.0	27936.0	275.6	93.4	.	369.0	1.0	4.7	.	1.3
				AVERAGE:	649.3	212.2	0.0	751.1	2.8	7.2	0.0	3.2
				SAMPLE SIZE:	25	12	4	25	25	12	4	25

Table F. (Continued)

Rates for Stratum 2

STAND	LIVE BOARD FEET PER ACRE				DEAD BOARD FEET PER ACRE				PERCENT OF TOTAL BOARD FEET PER ACRE			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	5048.7	401.6	336.5	5786.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	6982.1	0.0	517.3	7499.4	1526.3	.	0.0	1526.3	17.9	.	0.0	16.9
22	13617.7	1687.5	0.0	15305.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
23	17125.0	3241.3	0.0	20366.3	0.0	0.0	.	0.0	0.0	0.0	.	0.0
24	31049.3	1141.3	0.0	32190.6	510.9	0.0	.	510.9	1.6	0.0	.	1.6
25	5018.1	1953.1	0.0	6971.2	0.0	0.0	.	0.0	0.0	0.0	.	0.0
26	4995.1	2845.2	0.0	7840.3	288.7	0.0	.	288.7	5.5	0.0	.	3.6
27	1970.6	3551.4	0.0	5522.0	0.0	288.8	.	288.8	0.0	7.5	.	5.0
28	10522.5	5005.0	0.0	15527.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
29	1317.8	4282.8	0.0	5600.6	601.0	295.0	.	896.0	31.3	6.4	.	13.8
30	14322.3	0.0	0.0	14322.3	985.4	.	.	985.4	6.4	.	.	6.4
31	4903.3	64.7	0.0	4968.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
32	18742.3	833.8	0.0	19576.1	341.2	0.0	.	341.2	1.8	0.0	.	1.7
33	1357.8	4815.9	0.0	6173.7	42.2	0.0	.	42.2	3.0	0.0	.	0.7
34	1898.3	1791.5	0.0	3689.8	80.9	0.0	.	80.9	4.1	0.0	.	2.1
35	4539.2	1825.8	0.0	6365.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
36	1859.6	3769.1	0.0	5628.7	430.3	157.3	.	587.6	18.8	4.0	.	9.5
37	14360.2	513.8	753.9	15627.9	253.4	0.0	0.0	253.4	1.7	0.0	0.0	1.6
38	3890.2	0.0	0.0	3890.2	314.9	.	.	314.9	7.5	.	.	7.5
39	1483.9	0.0	0.0	1483.9	0.0	.	.	0.0	0.0	.	.	0.0
70	7752.0	5607.4	999.4	14358.8	489.1	220.0	0.0	709.1	5.9	3.8	0.0	4.7
71	1565.3	0.0	1292.8	2858.1	0.0	.	26.6	26.6	0.0	.	2.0	0.9
72	1652.2	4825.3	3752.1	10229.6	16.8	163.7	0.0	180.5	1.0	3.3	0.0	1.7
73	5413.1	6196.9	0.0	11610.0	656.6	1030.4	.	1687.0	10.8	14.3	.	12.7
74	12092.3	3612.5	0.0	15704.8	2546.5	276.6	.	2823.1	17.4	7.1	.	15.2
75	5426.1	1450.4	0.0	6876.5	1114.8	0.0	.	1114.8	17.0	0.0	.	14.0
76	12503.9	1065.0	0.0	13568.9	397.4	0.0	.	397.4	3.1	0.0	.	2.8
77	586.6	857.2	0.0	1443.8	0.0	0.0	.	0.0	0.0	0.0	.	0.0
78	13140.1	339.6	0.0	13479.7	0.0	117.0	.	117.0	0.0	25.6	.	0.9
79	13231.9	0.0	0.0	13231.9	36.5	.	.	36.5	0.3	.	.	0.3
80	24494.0	15.1	0.0	24509.1	783.6	0.0	.	783.6	3.1	0.0	.	3.1
81	2824.9	251.8	0.0	3076.7	0.0	0.0	.	0.0	0.0	0.0	.	0.0
82	7553.3	0.0	0.0	7553.3	0.0	.	.	0.0	0.0	.	.	0.0
83	6152.5	0.0	0.0	6152.5	261.4	.	.	261.4	4.1	.	.	4.1
84	2323.1	2196.5	0.0	4519.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
85	3439.5	99.8	0.0	3539.3	0.0	343.1	.	343.1	0.0	77.5	.	8.8
87	6310.7	0.0	0.0	6310.7	0.0	.	.	0.0	0.0	.	.	0.0
88	10343.0	0.0	0.0	10343.0	1279.2	.	.	1279.2	11.0	.	.	11.0
89	1496.9	0.0	0.0	1496.9	0.0	.	.	0.0	0.0	.	.	0.0
				AVERAGE:	332.2	103.3	4.4	407.1	4.5	5.3	0.3	3.9
				SAMPLE SIZE:	39	28	6	39	39	28	6	39

Table F. (Continued)

Rates for Stratum 3

STAND	LIVE BOARD FEET PER ACRE				DEAD BOARD FEET PER ACRE				PERCENT OF TOTAL BOARD FEET PER ACRE			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
15	5758.6	0.0	0.0	5758.6	0.0	.	.	0.0	0.0	.	.	0.0
16	8937.2	0.0	0.0	8937.2	0.0	.	.	0.0	0.0	.	.	0.0
18	10207.2	0.0	0.0	10207.2	0.0	.	.	0.0	0.0	.	.	0.0
40	21927.2	509.2	0.0	22436.4	439.5	0.0	.	439.5	2.0	0.0	.	1.9
41	2389.3	776.7	0.0	3166.0	0.0	0.0	.	0.0	0.0	0.0	.	0.0
42	4136.8	0.0	201.0	4337.8	220.0	.	0.0	220.0	5.0	.	0.0	4.8
43	6402.1	263.4	0.0	6665.5	0.0	0.0	.	0.0	0.0	0.0	.	0.0
45	6123.7	0.0	0.0	6123.7	0.0	.	.	0.0	0.0	.	.	0.0
48	8692.0	0.0	0.0	8692.0	0.0	.	.	0.0	0.0	.	.	0.0
49	10013.2	0.0	0.0	10013.2	128.0	.	.	128.0	1.3	.	.	1.3
50	6248.5	0.0	0.0	6248.5	2469.1	.	.	2469.1	28.3	.	.	28.3
51	2775.5	0.0	0.0	2775.5	0.0	.	.	0.0	0.0	.	.	0.0
52	2160.6	0.0	0.0	2160.6	99.8	.	.	99.8	4.4	.	.	4.4
53	7419.8	0.0	0.0	7419.8	0.0	.	.	0.0	0.0	.	.	0.0
54	864.9	0.0	0.0	864.9	0.0	.	.	0.0	0.0	.	.	0.0
55	8717.3	0.0	0.0	8717.3	1334.2	.	.	1334.2	13.3	.	.	13.3
56	3380.0	0.0	0.0	3380.0	0.0	.	.	0.0	0.0	.	.	0.0
57	22058.2	0.0	0.0	22058.2	88.8	.	.	88.8	0.4	.	.	0.4
90	12014.9	841.8	0.0	12856.7	303.1	0.0	.	303.1	2.5	0.0	.	2.3
91	3278.5	3731.2	0.0	7009.7	0.0	325.0	.	325.0	0.0	8.0	.	4.4
92	5780.2	2981.8	0.0	8762.0	1328.5	0.0	.	1328.5	18.7	0.0	.	13.2
93	18055.4	4119.8	0.0	22175.2	0.0	93.3	.	93.3	0.0	2.2	.	0.4
94	7919.5	1476.9	0.0	9396.4	14.2	0.0	.	14.2	0.2	0.0	.	0.2
95	9699.6	997.5	0.0	10697.1	37.0	0.0	.	37.0	0.4	0.0	.	0.3
96	21808.3	6066.0	0.0	27874.3	3348.6	542.5	.	3891.1	13.3	8.2	.	12.2
97	16152.3	347.8	0.0	16500.1	739.1	0.0	.	739.1	4.4	0.0	.	4.3
98	3928.5	0.0	0.0	3928.5	0.0	.	.	0.0	0.0	.	.	0.0
99	3490.1	0.0	0.0	3490.1	0.0	.	.	0.0	0.0	.	.	0.0
100	11521.0	4862.6	0.0	16383.6	441.4	1594.3	.	2035.7	3.7	24.7	.	11.1
101	7461.0	1064.6	0.0	8525.6	0.0	0.0	.	0.0	0.0	0.0	.	0.0
102	6677.0	0.0	0.0	6677.0	0.0	.	.	0.0	0.0	.	.	0.0
103	8935.4	0.0	0.0	8935.4	0.0	.	.	0.0	0.0	.	.	0.0
104	18227.5	0.0	0.0	18227.5	0.0	.	.	0.0	0.0	.	.	0.0
105	9603.5	0.0	0.0	9603.5	0.0	.	.	0.0	0.0	.	.	0.0
106	7359.8	0.0	0.0	7359.8	0.0	.	.	0.0	0.0	.	.	0.0
107	5629.6	0.0	0.0	5629.6	0.0	.	.	0.0	0.0	.	.	0.0
108	8167.9	0.0	0.0	8167.9	0.0	.	.	0.0	0.0	.	.	0.0
109	5954.9	0.0	0.0	5954.9	305.7	.	.	305.7	4.9	.	.	4.9
				AVERAGE:	297.3	196.5	0.0	364.5	2.7	3.3	0.0	2.8
				SAMPLE SIZE:	38	13	1	38	38	13	1	38
				OVERALL AVERAGE:	396.9	150.8	2.4	475.6	3.4	5.3	0.2	3.3
				SAMPLE SIZE:	102	53	11	102	102	53	11	102

Table G. Growth Loss Rates in Basal Area (Square Feet) per Acre by Species, Stand, and Stratum.

Rates for Stratum 2

STAND	ACTUAL BASAL AREA PER ACRE DF	GF	SAF	TOTAL	EXPECTED BASAL AREA PER ACRE DF	GF	SAF	TOTAL	LOSS PER ACRE DF	GF	SAF	TOTAL	PERCENT OF EXPECTED DF	GF	SAF	TOTAL
20	58.0	22.0	12.0	92.0	62.2	24.5	13.2	99.9	4.2	2.5	1.2	7.9	6.7	10.3	9.2	7.9
21	52.0	0.0	8.0	60.0	55.8	.	8.6	64.3	3.8	.	0.6	4.3	6.7	.	6.8	6.7
22	106.0	34.0	0.0	140.0	113.3	37.2	.	150.6	7.3	3.2	.	10.6	6.5	8.7	.	7.0
23	94.0	30.0	0.0	124.0	94.1	32.5	.	126.7	0.1	2.6	.	2.7	0.1	7.9	.	2.1
24	195.0	7.5	0.0	202.5	208.4	7.9	.	216.3	13.4	0.4	.	13.8	6.4	5.2	.	6.4
25	67.3	29.1	0.0	96.4	70.3	31.5	.	101.8	3.0	2.4	.	5.5	4.3	7.8	.	5.4
26	42.0	54.0	0.0	96.0	43.8	59.2	.	103.0	1.8	5.2	.	7.0	4.1	8.8	.	6.8
27	22.0	38.0	0.0	60.0	23.0	43.6	.	66.6	1.0	5.6	.	6.6	4.3	12.8	.	9.9
28	48.0	70.0	0.0	118.0	49.1	74.9	.	124.0	1.1	4.9	.	6.0	2.2	6.6	.	4.8
29	11.7	70.0	0.0	81.7	12.1	75.5	.	87.6	0.5	5.5	.	5.9	4.0	7.2	.	6.8
30	86.0	0.0	0.0	86.0	89.0	.	.	89.0	3.0	.	.	3.0	3.3	.	.	3.3
31	68.0	4.0	0.0	72.0	74.4	4.4	.	78.8	6.4	0.4	.	6.8	8.6	9.3	.	8.6
32	100.0	3.1	0.0	103.1	103.1	3.1	.	106.2	3.1	0.1	.	3.1	3.0	2.2	.	2.9
33	8.9	63.3	0.0	72.2	9.2	67.3	.	76.4	0.3	3.9	.	4.2	3.1	5.8	.	5.5
34	16.0	34.0	0.0	50.0	16.6	35.6	.	52.3	0.7	1.6	.	2.3	4.0	4.5	.	4.4
35	42.0	30.0	0.0	72.0	43.9	32.8	.	76.7	1.9	2.8	.	4.7	4.3	8.6	.	6.1
36	16.0	42.0	0.0	58.0	16.8	45.4	.	62.2	0.8	3.4	.	4.2	4.9	7.6	.	6.8
37	144.0	4.0	16.0	164.0	153.3	4.2	17.4	174.8	9.3	0.2	1.4	10.8	6.0	4.8	7.9	6.2
38	34.0	0.0	0.0	34.0	34.6	.	.	34.6	0.6	.	.	0.6	1.7	.	.	1.7
39	35.4	0.0	0.0	35.4	39.4	.	.	39.4	4.0	.	.	4.0	10.2	.	.	10.2
70	56.0	66.0	18.0	140.0	58.1	73.2	19.6	150.9	2.1	7.2	1.6	10.9	3.5	9.8	8.4	7.2
71	12.0	0.0	32.0	44.0	12.3	.	34.3	46.6	0.3	.	2.3	2.6	2.6	.	6.6	5.5
72	20.0	44.0	38.0	102.0	20.9	47.0	40.8	108.6	0.9	3.0	2.8	6.6	4.1	6.3	6.8	6.1
73	36.0	68.0	0.0	104.0	38.5	75.9	.	114.4	2.5	7.9	.	10.4	6.5	10.5	.	9.1
74	74.0	28.0	0.0	102.0	77.6	31.8	.	109.4	3.6	3.7	.	7.4	4.7	11.8	.	6.7
75	70.0	56.0	0.0	126.0	73.8	62.3	.	136.1	3.8	6.3	.	10.1	5.2	10.1	.	7.4
76	112.0	5.3	0.0	117.3	116.1	5.6	.	121.7	4.1	0.2	.	4.3	3.5	4.1	.	3.6
77	12.0	20.0	0.0	32.0	12.7	21.8	.	34.5	0.7	1.8	.	2.5	5.4	8.4	.	7.3
78	105.4	12.7	0.0	118.2	110.0	14.0	.	124.0	4.5	1.3	.	5.8	4.1	9.2	.	4.7
79	106.3	0.0	0.0	106.3	113.2	.	.	113.2	7.0	.	.	7.0	6.2	.	.	6.2
80	154.5	0.7	0.0	155.2	165.5	0.8	.	166.3	11.1	0.1	.	11.1	6.7	9.2	.	6.7
81	42.4	4.8	0.0	47.2	43.0	5.3	.	48.3	0.6	0.5	.	1.1	1.5	8.9	.	2.3
82	52.6	0.0	0.0	52.6	55.0	.	.	55.0	2.4	.	.	2.4	4.4	.	.	4.4
83	122.0	0.0	0.0	122.0	125.8	.	.	125.8	3.8	.	.	3.8	3.0	.	.	3.0
84	20.0	32.0	0.0	52.0	20.8	33.7	.	54.6	0.8	1.7	.	2.6	4.0	5.1	.	4.7
85	50.0	6.0	0.0	56.0	51.1	6.8	.	57.9	1.1	0.8	.	1.9	2.2	11.8	.	3.3
87	98.0	0.0	0.0	98.0	102.4	.	.	102.4	4.4	.	.	4.4	4.2	.	.	4.2
88	124.0	2.0	0.0	126.0	127.2	2.2	.	129.4	3.2	0.2	.	3.5	2.5	9.9	.	2.7
89	36.0	0.0	0.0	36.0	40.8	.	.	40.8	4.8	.	.	4.8	11.7	.	.	11.7
								AVERAGE:	3.3	2.7	1.6	5.6	4.6	8.0	7.6	5.8
								SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table G. (Continued)

Rates for Stratum 3

STAND	ACTUAL BASAL AREA PER ACRE DF	GF	SAF	TOTAL	EXPECTED BASAL AREA PER ACRE DF	GF	SAF	TOTAL	LOSS PER ACRE DF	GF	SAF	TOTAL	PERCENT OF EXPECTED DF	GF	SAF	TOTAL
15	64.0	0.0	0.0	64.0	68.6	.	.	68.6	4.6	.	.	4.6	6.8	.	.	6.8
16	80.0	0.0	0.0	80.0	83.6	.	.	83.6	3.6	.	.	3.6	4.3	.	.	4.3
18	94.0	0.0	0.0	94.0	99.4	.	.	99.4	5.4	.	.	5.4	5.5	.	.	5.5
40	131.1	6.7	0.0	137.8	134.6	7.2	.	141.7	3.4	0.5	.	4.0	2.6	7.2	.	2.8
41	60.0	16.0	0.0	76.0	58.9	17.4	.	76.3	-1.1	1.5	.	0.3	-1.9	8.4	.	0.4
42	42.0	0.0	4.0	46.0	42.8	.	4.3	47.1	0.8	.	0.3	1.1	1.8	.	7.2	2.3
43	60.0	2.0	0.0	62.0	61.6	2.1	.	63.8	1.6	0.1	.	1.8	2.7	5.7	.	2.8
45	46.7	0.0	0.0	46.7	47.8	.	.	47.8	1.1	.	.	1.1	2.4	.	.	2.4
48	46.0	0.0	0.0	46.0	46.0	.	.	46.0	0.1	.	.	0.1	0.1	.	.	0.1
49	70.0	0.0	0.0	70.0	72.0	.	.	72.0	2.0	.	.	2.0	2.8	.	.	2.8
50	76.0	0.0	0.0	76.0	82.0	.	.	82.0	6.0	.	.	6.0	7.4	.	.	7.4
51	50.0	0.0	0.0	50.0	48.4	.	.	48.4	-1.6	.	.	-1.6	-3.3	.	.	-3.3
52	44.0	0.0	0.0	44.0	46.3	.	.	46.3	2.3	.	.	2.3	5.0	.	.	5.0
53	58.0	0.0	0.0	58.0	61.4	.	.	61.4	3.4	.	.	3.4	5.5	.	.	5.5
54	25.3	0.0	0.0	25.3	26.3	.	.	26.3	1.0	.	.	1.0	3.9	.	.	3.9
55	85.8	0.0	0.0	85.8	90.8	.	.	90.8	5.0	.	.	5.0	5.5	.	.	5.5
56	28.0	0.0	0.0	28.0	28.2	.	.	28.2	0.2	.	.	0.2	0.8	.	.	0.8
57	127.2	0.0	0.0	127.2	130.3	.	.	130.3	3.1	.	.	3.1	2.4	.	.	2.4
90	118.3	13.3	0.0	131.7	121.0	14.6	.	135.6	2.6	1.3	.	3.9	2.2	8.7	.	2.9
91	20.0	38.0	0.0	58.0	20.6	39.4	.	59.9	0.6	1.4	.	1.9	2.9	3.5	.	3.3
92	62.0	24.0	0.0	86.0	62.3	25.7	.	87.9	0.3	1.7	.	1.9	0.4	6.5	.	2.2
93	114.0	26.0	0.0	140.0	119.2	27.6	.	146.9	5.2	1.6	.	6.8	4.4	5.9	.	4.7
94	80.0	31.2	0.0	111.2	83.4	36.9	.	120.3	3.4	5.7	.	9.1	4.1	15.4	.	7.6
95	79.3	17.0	0.0	96.3	83.6	18.7	.	102.3	4.3	1.7	.	6.0	5.2	8.9	.	5.9
96	180.0	40.0	0.0	220.0	191.0	42.4	.	233.4	11.0	2.4	.	13.4	5.8	5.6	.	5.7
97	134.0	4.0	0.0	138.0	141.8	4.3	.	146.1	7.8	0.3	.	8.1	5.5	7.2	.	5.6
98	52.0	0.0	0.0	52.0	54.1	.	.	54.1	2.1	.	.	2.1	3.9	.	.	3.9
99	71.7	0.0	0.0	71.7	74.3	.	.	74.3	2.6	.	.	2.6	3.5	.	.	3.5
100	60.0	31.7	0.0	91.7	62.8	33.5	.	96.3	2.8	1.9	.	4.7	4.5	5.5	.	4.8
101	130.9	21.8	0.0	152.7	136.2	24.1	.	160.2	5.2	2.3	.	7.5	3.8	9.3	.	4.7
102	87.3	0.0	0.0	87.3	89.6	.	.	89.6	2.4	.	.	2.4	2.6	.	.	2.6
103	134.0	0.0	0.0	134.0	133.4	.	.	133.4	-0.5	.	.	-0.5	-0.4	.	.	-0.4
104	228.0	0.0	0.0	228.0	233.9	.	.	233.9	5.9	.	.	5.9	2.5	.	.	2.5
105	100.0	0.0	0.0	100.0	103.5	.	.	103.5	3.5	.	.	3.5	3.4	.	.	3.4
106	81.8	0.0	0.0	81.8	82.0	.	.	82.0	0.2	.	.	0.2	0.3	.	.	0.3
107	62.2	1.1	0.0	63.3	63.9	1.3	.	65.1	1.7	0.1	.	1.8	2.6	11.2	.	2.8
108	90.0	0.0	0.0	90.0	90.6	.	.	90.6	0.6	.	.	0.6	0.7	.	.	0.7
109	66.0	0.0	0.0	66.0	67.0	.	.	67.0	1.0	.	.	1.0	1.6	.	.	1.6
								AVERAGE:	2.7	1.6	0.3	3.3	3.0	7.8	7.2	3.3
								SAMPLE SIZE:	38	14	1	38	38	14	1	38
								OVERALL AVERAGE:	3.0	2.4	1.5	4.5	3.8	8.0	7.5	4.6
								SAMPLE SIZE:	77	43	7	77	77	43	7	77

Table H. Growth Loss Rates in Volume (Cubic Feet) per Acre by Species, Stand, and Stratum. Expected volumes were calculated assuming zero height growth in years with known budworm defoliation.

Rates for Stratum 2

	ACTUAL CUBIC FEET PER ACRE				EXPECTED CUBIC FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	1273.7	315.0	152.6	1741.3	1394.0	387.6	189.7	1971.3	120.3	72.6	37.1	230.0	8.6	18.7	19.6	11.7
21	1457.9	0.0	174.6	1632.5	1591.5	.	192.9	1784.4	133.6	.	18.3	151.9	8.4	.	9.5	8.5
22	2921.1	660.5	0.0	3581.6	3178.2	762.8	.	3941.0	257.1	102.3	.	359.4	8.1	13.4	.	9.1
23	3261.3	768.8	0.0	4030.1	3312.8	867.2	.	4180.0	51.5	98.4	.	149.9	1.6	11.3	.	3.6
24	6221.7	235.7	0.0	6457.4	7037.7	266.3	.	7304.0	816.0	30.6	.	846.6	11.6	11.5	.	11.6
25	1466.8	627.9	0.0	2094.7	1566.4	705.7	.	2272.1	99.6	77.8	.	177.4	6.4	11.0	.	7.8
26	1188.4	1136.3	0.0	2324.7	1259.4	1325.9	.	2585.3	71.0	189.6	.	260.6	5.6	14.3	.	10.1
27	555.4	956.7	0.0	1512.1	593.0	1152.6	.	1745.6	37.6	195.9	.	233.5	6.3	17.0	.	13.4
28	1802.4	1549.3	0.0	3351.7	1842.7	1724.3	.	3567.0	40.3	175.0	.	215.3	2.2	10.1	.	6.0
29	279.4	1511.2	0.0	1790.6	294.9	1694.8	.	1989.7	15.5	183.6	.	199.1	5.3	10.8	.	10.0
30	2729.6	0.0	0.0	2729.6	2840.1	.	.	2840.1	110.5	.	.	110.5	3.9	.	.	3.9
31	1497.0	73.0	0.0	1570.0	1690.1	84.9	.	1775.0	193.1	11.9	.	205.0	11.4	14.0	.	11.5
32	3446.9	128.2	0.0	3575.1	3589.8	131.7	.	3721.5	142.9	3.5	.	146.4	4.0	2.7	.	3.9
33	277.6	1439.0	0.0	1716.6	288.5	1572.2	.	1860.7	10.9	133.2	.	144.1	3.8	8.5	.	7.7
34	387.2	691.8	0.0	1079.0	404.3	747.4	.	1151.7	17.1	55.6	.	72.7	4.2	7.4	.	6.3
35	1137.1	635.7	0.0	1772.8	1206.8	725.8	.	1932.6	69.7	90.1	.	159.8	5.8	12.4	.	8.3
36	361.5	1065.1	0.0	1426.6	378.7	1190.0	.	1568.7	17.2	124.9	.	142.1	4.5	10.5	.	9.1
37	3368.5	103.3	274.4	3746.2	3656.2	109.5	318.9	4084.6	287.7	6.2	44.5	338.4	7.9	5.7	14.0	8.3
38	796.9	0.0	0.0	796.9	817.5	.	.	817.5	20.6	.	.	20.6	2.5	.	.	2.5
39	601.3	0.0	0.0	601.3	718.4	.	.	718.4	117.1	.	.	117.1	16.3	.	.	16.3
70	1647.1	1479.4	316.3	3442.8	1744.2	1744.8	368.9	3857.9	97.1	265.4	52.6	415.1	5.6	15.2	14.3	10.8
71	303.7	0.0	520.1	823.8	313.2	.	575.9	889.1	9.5	.	55.8	65.3	3.0	.	9.7	7.3
72	454.6	1120.0	928.1	2502.7	488.7	1226.3	1032.8	2747.8	34.1	106.3	104.7	245.1	7.0	8.7	10.1	8.9
73	1092.9	1630.7	0.0	2723.6	1205.2	1930.9	.	3136.1	112.3	300.2	.	412.5	9.3	15.5	.	13.2
74	2398.8	788.3	0.0	3187.1	2553.3	927.2	.	3480.5	154.5	138.9	.	293.4	6.1	15.0	.	8.4
75	1756.8	979.3	0.0	2736.1	1897.2	1201.1	.	3098.3	140.4	221.8	.	362.2	7.4	18.5	.	11.7
76	3219.7	191.6	0.0	3411.3	3405.5	201.5	.	3607.0	185.8	9.9	.	195.7	5.5	4.9	.	5.4
77	222.9	415.1	0.0	638.0	242.0	462.1	.	704.1	19.1	47.0	.	66.1	7.9	10.2	.	9.4
78	2832.7	248.9	0.0	3081.6	2974.3	290.2	.	3264.5	141.6	41.3	.	182.9	4.8	14.2	.	5.6
79	2980.2	0.0	0.0	2980.2	3227.2	.	.	3227.2	247.0	.	.	247.0	7.7	.	.	7.7
80	4787.3	13.9	0.0	4801.2	5228.3	16.3	.	5244.6	441.0	2.4	.	443.4	8.4	14.7	.	8.5
81	949.1	92.8	0.0	1041.9	977.4	108.2	.	1085.6	28.3	15.4	.	43.7	2.9	14.2	.	4.0
82	1513.4	0.0	0.0	1513.4	1589.6	.	.	1589.6	76.2	.	.	76.2	4.8	.	.	4.8
83	2306.1	0.0	0.0	2306.1	2397.5	.	.	2397.5	91.4	.	.	91.4	3.8	.	.	3.8
84	529.5	698.9	0.0	1228.4	563.4	766.1	.	1329.5	33.9	67.2	.	101.1	6.0	8.8	.	7.6
85	1085.2	67.2	0.0	1152.4	1147.8	92.5	.	1240.3	62.6	25.3	.	87.9	5.5	27.4	.	7.1
87	2277.0	0.0	0.0	2277.0	2425.2	.	.	2425.2	148.2	.	.	148.2	6.1	.	.	6.1
88	2853.8	36.0	0.0	2889.8	2962.5	43.1	.	3005.6	108.7	7.1	.	115.8	3.7	16.5	.	3.9
89	608.2	0.0	0.0	608.2	738.0	.	.	738.0	129.8	.	.	129.8	17.6	.	.	17.6
								AVERAGE:	125.4	96.5	52.2	205.2	6.4	12.5	12.8	8.2
								SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table H. (Continued)

Rates for Stratum 3

STAND	ACTUAL CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	EXPECTED CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	LOSS PER ACRE DF	GF	SAF	TOTAL	PERCENT OF EXPECTED DF	GF	SAF	TOTAL
15	1564.2	0.0	0.0	1564.2	1688.0	.	.	1688.0	123.8	.	.	123.8	7.3	.	.	7.3
16	2226.1	0.0	0.0	2226.1	2346.9	.	.	2346.9	120.8	.	.	120.8	5.1	.	.	5.1
18	2412.3	0.0	0.0	2412.3	2576.8	.	.	2576.8	164.5	.	.	164.5	6.4	.	.	6.4
40	4110.1	160.1	0.0	4270.2	4234.2	176.9	.	4411.1	124.1	16.8	.	140.9	2.9	9.5	.	3.2
41	1200.3	336.1	0.0	1536.4	1169.7	378.9	.	1548.6	-30.6	42.8	.	12.2	-2.6	11.3	.	0.8
42	1031.7	0.0	86.1	1117.8	1056.7	.	95.5	1152.2	25.0	.	9.4	34.4	2.4	.	9.8	3.0
43	1570.9	58.0	0.0	1628.9	1623.7	62.2	.	1685.9	52.8	4.2	.	57.0	3.3	6.8	.	3.4
45	1316.4	0.0	0.0	1316.4	1348.8	.	.	1348.8	32.4	.	.	32.4	2.4	.	.	2.4
48	1612.5	0.0	0.0	1612.5	1627.3	.	.	1627.3	14.8	.	.	14.8	0.9	.	.	0.9
49	2093.2	0.0	0.0	2093.2	2186.7	.	.	2186.7	93.5	.	.	93.5	4.3	.	.	4.3
50	1618.0	0.0	0.0	1618.0	1800.0	.	.	1800.0	182.0	.	.	182.0	10.1	.	.	10.1
51	994.1	0.0	0.0	994.1	962.4	.	.	962.4	-31.7	.	.	-31.7	-3.3	.	.	-3.3
52	897.2	0.0	0.0	897.2	986.5	.	.	986.5	89.3	.	.	89.3	9.1	.	.	9.1
53	1555.2	0.0	0.0	1555.2	1670.7	.	.	1670.7	115.5	.	.	115.5	6.9	.	.	6.9
54	451.5	0.0	0.0	451.5	479.0	.	.	479.0	27.5	.	.	27.5	5.7	.	.	5.7
55	2178.1	0.0	0.0	2178.1	2360.0	.	.	2360.0	181.9	.	.	181.9	7.7	.	.	7.7
56	732.9	0.0	0.0	732.9	744.9	.	.	744.9	12.0	.	.	12.0	1.6	.	.	1.6
57	4297.3	0.0	0.0	4297.3	4464.6	.	.	4464.6	167.3	.	.	167.3	3.7	.	.	3.7
90	3053.9	275.2	0.0	3329.1	3175.0	318.4	.	3493.4	121.1	43.2	.	164.3	3.8	13.6	.	4.7
91	645.5	937.7	0.0	1583.2	671.2	986.9	.	1658.1	25.7	49.2	.	74.9	3.8	5.0	.	4.5
92	1656.9	731.2	0.0	2388.1	1674.9	801.6	.	2476.5	18.0	70.4	.	88.4	1.1	8.8	.	3.6
93	3735.3	833.4	0.0	4568.7	3944.8	897.1	.	4841.9	209.5	63.7	.	273.2	5.3	7.1	.	5.6
94	2043.6	614.5	0.0	2658.1	2161.0	793.0	.	2954.0	117.4	178.5	.	295.9	5.4	22.5	.	10.0
95	2256.4	376.7	0.0	2633.1	2408.0	429.7	.	2837.7	151.6	53.0	.	204.6	6.3	12.3	.	7.2
96	5458.6	1316.0	0.0	6774.6	5867.3	1404.3	.	7271.6	408.7	88.3	.	497.0	7.0	6.3	.	6.8
97	3965.3	110.5	0.0	4075.8	4258.3	122.0	.	4380.3	293.0	11.5	.	304.5	6.9	9.4	.	7.0
98	1200.9	0.0	0.0	1200.9	1273.8	.	.	1273.8	72.9	.	.	72.9	5.7	.	.	5.7
99	1473.4	0.0	0.0	1473.4	1557.7	.	.	1557.7	84.3	.	.	84.3	5.4	.	.	5.4
100	2138.5	1015.2	0.0	3153.7	2264.7	1091.1	.	3355.8	126.2	75.9	.	202.1	5.6	7.0	.	6.0
101	2718.0	423.4	0.0	3141.4	2845.8	493.6	.	3339.4	127.8	70.2	.	198.0	4.5	14.2	.	5.9
102	1967.4	0.0	0.0	1967.4	2037.5	.	.	2037.5	70.1	.	.	70.1	3.4	.	.	3.4
103	2579.2	0.0	0.0	2579.2	2562.6	.	.	2562.6	-16.6	.	.	-16.6	-0.6	.	.	-0.6
104	4956.9	0.0	0.0	4956.9	5101.6	.	.	5101.6	144.7	.	.	144.7	2.8	.	.	2.8
105	2449.9	0.0	0.0	2449.9	2549.7	.	.	2549.7	99.8	.	.	99.8	3.9	.	.	3.9
106	2072.4	0.0	0.0	2072.4	2078.2	.	.	2078.2	5.8	.	.	5.8	0.3	.	.	0.3
107	1532.5	18.0	0.0	1550.5	1579.3	22.0	.	1601.3	46.8	4.0	.	50.8	3.0	18.2	.	3.2
108	2180.6	0.0	0.0	2180.6	2199.3	.	.	2199.3	18.7	.	.	18.7	0.9	.	.	0.9
109	1565.0	0.0	0.0	1565.0	1594.8	.	.	1594.8	29.8	.	.	29.8	1.9	.	.	1.9
								AVERAGE:	95.3	55.1	9.4	115.8	4.0	10.8	9.8	4.4
								SAMPLE SIZE:	38	14	1	38	38	14	1	38
								OVERALL AVERAGE:	110.5	83.0	46.1	161.1	5.2	12.0	12.4	6.3
								SAMPLE SIZE:	77	43	7	77	77	43	7	77

Table I. Growth Loss Rates in Volume (Cubic Feet) per Acre by Species, Stand, and Stratum. Expected volumes were calculated assuming no height growth loss due to budworm-caused tree injury.

Rates for Stratum 2

	ACTUAL CUBIC FEET PER ACRE				EXPECTED CUBIC FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	1273.7	315.0	152.6	1741.3	1373.4	378.7	186.5	1938.6	99.7	63.7	33.9	197.3	7.3	16.8	18.2	10.2
21	1457.9	0.0	174.6	1632.5	1568.2	.	188.9	1757.1	110.3	.	14.3	124.6	7.0	.	7.6	7.1
22	2921.1	660.5	0.0	3581.6	3119.7	740.8	.	3860.5	198.6	80.3	.	278.9	6.4	10.8	.	7.2
23	3261.3	768.8	0.0	4030.1	3265.4	841.3	.	4106.7	4.1	72.5	.	76.6	0.1	8.6	.	1.9
24	6221.7	235.7	0.0	6457.4	6658.8	249.0	.	6907.8	437.1	13.3	.	450.4	6.6	5.3	.	6.5
25	1466.8	627.9	0.0	2094.7	1548.7	693.0	.	2241.7	81.9	65.1	.	147.0	5.3	9.4	.	6.6
26	1188.4	1136.3	0.0	2324.7	1242.6	1290.4	.	2533.0	54.2	154.1	.	208.3	4.4	11.9	.	8.2
27	555.4	956.7	0.0	1512.1	586.0	1126.4	.	1712.4	30.6	169.7	.	200.3	5.2	15.1	.	11.7
28	1802.4	1549.3	0.0	3351.7	1841.9	1694.4	.	3536.3	39.5	145.1	.	184.6	2.1	8.6	.	5.2
29	279.4	1511.2	0.0	1790.6	291.4	1665.2	.	1956.6	12.0	154.0	.	166.0	4.1	9.2	.	8.5
30	2729.6	0.0	0.0	2729.6	2823.9	.	.	2823.9	94.3	.	.	94.3	3.3	.	.	3.3
31	1497.0	73.0	0.0	1570.0	1653.2	82.6	.	1735.8	156.2	9.6	.	165.8	9.4	11.6	.	9.6
32	3446.9	128.2	0.0	3575.1	3551.8	131.4	.	3683.2	104.9	3.2	.	108.1	3.0	2.4	.	2.9
33	277.6	1439.0	0.0	1716.6	286.4	1552.8	.	1839.2	8.8	113.8	.	122.6	3.1	7.3	.	6.7
34	387.2	691.8	0.0	1079.0	400.4	733.0	.	1133.4	13.2	41.2	.	54.4	3.3	5.6	.	4.8
35	1137.1	635.7	0.0	1772.8	1191.8	710.6	.	1902.4	54.7	74.9	.	129.6	4.6	10.5	.	6.8
36	361.5	1065.1	0.0	1426.6	379.3	1159.1	.	1538.4	17.8	94.0	.	111.8	4.7	8.1	.	7.3
37	3368.5	103.3	274.4	3746.2	3610.3	108.5	313.5	4032.3	241.8	5.2	39.1	286.1	6.7	4.8	12.5	7.1
38	796.9	0.0	0.0	796.9	813.9	.	.	813.9	17.0	.	.	17.0	2.1	.	.	2.1
39	601.3	0.0	0.0	601.3	706.7	.	.	706.7	105.4	.	.	105.4	14.9	.	.	14.9
70	1647.1	1479.4	316.3	3442.8	1704.1	1684.2	356.7	3745.0	57.0	204.8	40.4	302.2	3.3	12.2	11.3	8.1
71	303.7	0.0	520.1	823.8	311.8	.	569.1	880.9	8.1	.	49.0	57.1	2.6	.	8.6	6.5
72	454.6	1120.0	928.1	2502.7	475.3	1195.4	999.0	2669.7	20.7	75.4	70.9	167.0	4.4	6.3	7.1	6.3
73	1092.9	1630.7	0.0	2723.6	1173.8	1858.8	.	3032.6	80.9	228.1	.	309.0	6.9	12.3	.	10.2
74	2398.8	788.3	0.0	3187.1	2524.2	907.8	.	3432.0	125.4	119.5	.	244.9	5.0	13.2	.	7.1
75	1756.8	979.3	0.0	2736.1	1869.2	1175.2	.	3044.4	112.4	195.9	.	308.3	6.0	16.7	.	10.1
76	3219.7	191.6	0.0	3411.3	3357.3	199.9	.	3557.2	137.6	8.3	.	145.9	4.1	4.2	.	4.1
77	222.9	415.1	0.0	638.0	242.0	462.1	.	704.1	19.1	47.0	.	66.1	7.9	10.2	.	9.4
78	2832.7	248.9	0.0	3081.6	2963.3	286.7	.	3250.0	130.6	37.8	.	168.4	4.4	13.2	.	5.2
79	2980.2	0.0	0.0	2980.2	3185.2	.	.	3185.2	205.0	.	.	205.0	6.4	.	.	6.4
80	4787.3	13.9	0.0	4801.2	5134.9	15.7	.	5150.6	347.6	1.8	.	349.4	6.8	11.5	.	6.8
81	949.1	92.8	0.0	1041.9	965.7	105.8	.	1071.5	16.6	13.0	.	29.6	1.7	12.3	.	2.8
82	1513.4	0.0	0.0	1513.4	1579.3	.	.	1579.3	65.9	.	.	65.9	4.2	.	.	4.2
83	2306.1	0.0	0.0	2306.1	2396.7	.	.	2396.7	90.6	.	.	90.6	3.8	.	.	3.8
84	529.5	698.9	0.0	1228.4	554.2	747.1	.	1301.3	24.7	48.2	.	72.9	4.5	6.5	.	5.6
85	1085.2	67.2	0.0	1152.4	1112.5	88.5	.	1201.0	27.3	21.3	.	48.6	2.5	24.1	.	4.0
87	2277.0	0.0	0.0	2277.0	2411.0	.	.	2411.0	134.0	.	.	134.0	5.6	.	.	5.6
88	2853.8	36.0	0.0	2889.8	2951.8	42.2	.	2994.0	98.0	6.2	.	104.2	3.3	14.7	.	3.5
89	608.2	0.0	0.0	608.2	727.6	.	.	727.6	119.4	.	.	119.4	16.4	.	.	16.4
								AVERAGE:	94.9	78.2	41.3	159.4	5.2	10.5	10.9	6.8
								SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table I. (Continued)

Rates for Stratum 3

STAND	ACTUAL CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	EXPECTED CUBIC FEET PER ACRE DF	GF	SAF	TOTAL	LOSS PER ACRE DF	GF	SAF	TOTAL	PERCENT OF EXPECTED DF	GF	SAF	TOTAL
15	1564.2	0.0	0.0	1564.2	1688.1	.	.	1688.1	123.9	.	.	123.9	7.3	.	.	7.3
16	2226.1	0.0	0.0	2226.1	2339.2	.	.	2339.2	113.1	.	.	113.1	4.8	.	.	4.8
18	2412.3	0.0	0.0	2412.3	2575.8	.	.	2575.8	163.5	.	.	163.5	6.3	.	.	6.3
40	4110.1	160.1	0.0	4270.2	4218.3	174.1	.	4392.4	108.2	14.0	.	122.2	2.6	8.0	.	2.8
41	1200.3	336.1	0.0	1536.4	1173.1	373.4	.	1546.5	-27.2	37.3	.	10.1	-2.3	10.0	.	0.7
42	1031.7	0.0	86.1	1117.8	1054.4	.	94.3	1148.7	22.7	.	8.2	30.9	2.2	.	8.7	2.7
43	1570.9	58.0	0.0	1628.9	1617.0	61.6	.	1678.6	46.1	3.6	.	49.7	2.9	5.8	.	3.0
45	1316.4	0.0	0.0	1316.4	1347.2	.	.	1347.2	30.8	.	.	30.8	2.3	.	.	2.3
48	1612.5	0.0	0.0	1612.5	1614.2	.	.	1614.2	1.7	.	.	1.7	0.1	.	.	0.1
49	2093.2	0.0	0.0	2093.2	2154.3	.	.	2154.3	61.1	.	.	61.1	2.8	.	.	2.8
50	1618.0	0.0	0.0	1618.0	1777.9	.	.	1777.9	159.9	.	.	159.9	9.0	.	.	9.0
51	994.1	0.0	0.0	994.1	953.1	.	.	953.1	-41.0	.	.	-41.0	-4.3	.	.	-4.3
52	897.2	0.0	0.0	897.2	963.4	.	.	963.4	66.2	.	.	66.2	6.9	.	.	6.9
53	1555.2	0.0	0.0	1555.2	1645.3	.	.	1645.3	90.1	.	.	90.1	5.5	.	.	5.5
54	451.5	0.0	0.0	451.5	475.6	.	.	475.6	24.1	.	.	24.1	5.1	.	.	5.1
55	2178.1	0.0	0.0	2178.1	2322.8	.	.	2322.8	144.7	.	.	144.7	6.2	.	.	6.2
56	732.9	0.0	0.0	732.9	739.2	.	.	739.2	6.3	.	.	6.3	0.9	.	.	0.9
57	4297.3	0.0	0.0	4297.3	4400.6	.	.	4400.6	103.3	.	.	103.3	2.3	.	.	2.3
90	3053.9	275.2	0.0	3329.1	3130.3	309.3	.	3439.6	76.4	34.1	.	110.5	2.4	11.0	.	3.2
91	645.5	937.7	0.0	1583.2	664.9	972.9	.	1637.8	19.4	35.2	.	54.6	2.9	3.6	.	3.3
92	1656.9	731.2	0.0	2388.1	1665.3	786.6	.	2451.9	8.4	55.4	.	63.8	0.5	7.0	.	2.6
93	3735.3	833.4	0.0	4568.7	3915.0	888.7	.	4803.7	179.7	55.3	.	235.0	4.6	6.2	.	4.9
94	2043.6	614.5	0.0	2658.1	2141.9	769.4	.	2911.3	98.3	154.9	.	253.2	4.6	20.1	.	8.7
95	2256.4	376.7	0.0	2633.1	2396.3	425.8	.	2822.1	139.9	49.1	.	189.0	5.8	11.5	.	6.7
96	5458.6	1316.0	0.0	6774.6	5839.7	1397.4	.	7237.1	381.1	81.4	.	462.5	6.5	5.8	.	6.4
97	3965.3	110.5	0.0	4075.8	4223.6	120.4	.	4344.0	258.3	9.9	.	268.2	6.1	8.2	.	6.2
98	1200.9	0.0	0.0	1200.9	1258.2	.	.	1258.2	57.3	.	.	57.3	4.6	.	.	4.6
99	1473.4	0.0	0.0	1473.4	1545.1	.	.	1545.1	71.7	.	.	71.7	4.6	.	.	4.6
100	2138.5	1015.2	0.0	3153.7	2236.0	1074.0	.	3312.0	99.5	58.8	.	158.3	4.4	5.5	.	4.8
101	2718.0	423.4	0.0	3141.4	2847.1	489.9	.	3337.0	129.1	66.5	.	195.6	4.5	13.6	.	5.9
102	1967.4	0.0	0.0	1967.4	2037.3	.	.	2037.3	69.9	.	.	69.9	3.4	.	.	3.4
103	2579.2	0.0	0.0	2579.2	2562.9	.	.	2562.9	-16.3	.	.	-16.3	-0.6	.	.	-0.6
104	4956.9	0.0	0.0	4956.9	5100.0	.	.	5100.0	143.1	.	.	143.1	2.8	.	.	2.8
105	2449.9	0.0	0.0	2449.9	2548.4	.	.	2548.4	98.5	.	.	98.5	3.9	.	.	3.9
106	2072.4	0.0	0.0	2072.4	2078.1	.	.	2078.1	5.7	.	.	5.7	0.3	.	.	0.3
107	1532.5	18.0	0.0	1550.5	1580.0	21.7	.	1601.7	47.5	3.7	.	51.2	3.0	17.1	.	3.2
108	2180.6	0.0	0.0	2180.6	2199.3	.	.	2199.3	18.7	.	.	18.7	0.9	.	.	0.9
109	1565.0	0.0	0.0	1565.0	1593.5	.	.	1593.5	28.5	.	.	28.5	1.8	.	.	1.8
								AVERAGE:	81.9	47.1	8.2	99.5	3.4	9.5	8.7	3.7
								SAMPLE SIZE:	38	14	1	38	38	14	1	38
								OVERALL AVERAGE:	88.5	68.1	36.5	129.8	4.3	10.2	10.6	5.3
								SAMPLE SIZE:	77	43	7	77	77	43	7	77

Table J. Growth Loss Rates in Volume (Cubic Feet) per Acre by Species, Stand, and Stratum. Expected volumes were calculated assuming a height growth reduction proportional to the reduction in diameter growth.

Rates for Stratum 2

	ACTUAL CUBIC FEET PER ACRE				EXPECTED CUBIC FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	1273.7	315.0	152.6	1741.3	1383.4	380.3	192.2	1955.9	109.7	65.3	39.6	214.6	7.9	17.2	20.6	11.0
21	1457.9	0.0	174.6	1632.5	1599.1	.	194.5	1793.6	141.2	.	19.9	161.1	8.8	.	10.2	9.0
22	2921.1	660.5	0.0	3581.6	3185.6	750.8	.	3936.4	264.5	90.3	.	354.8	8.3	12.0	.	9.0
23	3261.3	768.8	0.0	4030.1	3261.2	846.5	.	4107.7	-0.1	77.7	.	77.6	-0.0	9.2	.	1.9
24	6221.7	235.7	0.0	6457.4	6739.6	249.6	.	6989.2	517.9	13.9	.	531.8	7.7	5.6	.	7.6
25	1466.8	627.9	0.0	2094.7	1543.2	697.4	.	2240.6	76.4	69.5	.	145.9	5.0	10.0	.	6.5
26	1188.4	1136.3	0.0	2324.7	1258.0	1299.0	.	2557.0	69.6	162.7	.	232.3	5.5	12.5	.	9.1
27	555.4	956.7	0.0	1512.1	582.8	1150.1	.	1732.9	27.4	193.4	.	220.8	4.7	16.8	.	12.7
28	1802.4	1549.3	0.0	3351.7	1840.0	1702.2	.	3542.2	37.6	152.9	.	190.5	2.0	9.0	.	5.4
29	279.4	1511.2	0.0	1790.6	289.5	1693.7	.	1983.2	10.1	182.5	.	192.6	3.5	10.8	.	9.7
30	2729.6	0.0	0.0	2729.6	2835.5	.	.	2835.5	105.9	.	.	105.9	3.7	.	.	3.7
31	1497.0	73.0	0.0	1570.0	1673.9	83.3	.	1757.2	176.9	10.3	.	187.2	10.6	12.4	.	10.7
32	3446.9	128.2	0.0	3575.1	3578.5	131.6	.	3710.1	131.6	3.4	.	135.0	3.7	2.6	.	3.6
33	277.6	1439.0	0.0	1716.6	286.0	1569.5	.	1855.5	8.4	130.5	.	138.9	2.9	8.3	.	7.5
34	387.2	691.8	0.0	1079.0	399.3	734.1	.	1133.4	12.1	42.3	.	54.4	3.0	5.8	.	4.8
35	1137.1	635.7	0.0	1772.8	1206.1	715.4	.	1921.5	69.0	79.7	.	148.7	5.7	11.1	.	7.7
36	361.5	1065.1	0.0	1426.6	377.1	1192.4	.	1569.5	15.6	127.3	.	142.9	4.1	10.7	.	9.1
37	3368.5	103.3	274.4	3746.2	3622.6	108.7	320.0	4051.3	254.1	5.4	45.6	305.1	7.0	5.0	14.3	7.5
38	796.9	0.0	0.0	796.9	814.6	.	.	814.6	17.7	.	.	17.7	2.2	.	.	2.2
39	601.3	0.0	0.0	601.3	723.9	.	.	723.9	122.6	.	.	122.6	16.9	.	.	16.9
70	1647.1	1479.4	316.3	3442.8	1704.0	1708.4	367.6	3780.0	56.9	229.0	51.3	337.2	3.3	13.4	14.0	8.9
71	303.7	0.0	520.1	823.8	311.4	.	574.3	885.7	7.7	.	54.2	61.9	2.5	.	9.4	7.0
72	454.6	1120.0	928.1	2502.7	476.4	1209.5	1029.4	2715.3	21.8	89.5	101.3	212.6	4.6	7.4	9.8	7.8
73	1092.9	1630.7	0.0	2723.6	1192.7	1909.2	.	3101.9	99.8	278.5	.	378.3	8.4	14.6	.	12.2
74	2398.8	788.3	0.0	3187.1	2557.5	914.2	.	3471.7	158.7	125.9	.	284.6	6.2	13.8	.	8.2
75	1756.8	979.3	0.0	2736.1	1890.2	1174.2	.	3064.4	133.4	194.9	.	328.3	7.1	16.6	.	10.7
76	3219.7	191.6	0.0	3411.3	3361.2	200.3	.	3561.5	141.5	8.7	.	150.2	4.2	4.3	.	4.2
77	222.9	415.1	0.0	638.0	240.1	465.9	.	706.0	17.2	50.8	.	68.0	7.2	10.9	.	9.6
78	2832.7	248.9	0.0	3081.6	2986.2	288.4	.	3274.6	153.5	39.5	.	193.0	5.1	13.7	.	5.9
79	2980.2	0.0	0.0	2980.2	3190.1	.	.	3190.1	209.9	.	.	209.9	6.6	.	.	6.6
80	4787.3	13.9	0.0	4801.2	5209.2	15.9	.	5225.1	421.9	2.0	.	423.9	8.1	12.6	.	8.1
81	949.1	92.8	0.0	1041.9	973.7	106.3	.	1080.0	24.6	13.5	.	38.1	2.5	12.7	.	3.5
82	1513.4	0.0	0.0	1513.4	1601.9	.	.	1601.9	88.5	.	.	88.5	5.5	.	.	5.5
83	2306.1	0.0	0.0	2306.1	2379.1	.	.	2379.1	73.0	.	.	73.0	3.1	.	.	3.1
84	529.5	698.9	0.0	1228.4	563.5	763.4	.	1326.9	34.0	64.5	.	98.5	6.0	8.4	.	7.4
85	1085.2	67.2	0.0	1152.4	1115.4	88.7	.	1204.1	30.2	21.5	.	51.7	2.7	24.2	.	4.3
87	2277.0	0.0	0.0	2277.0	2413.6	.	.	2413.6	136.6	.	.	136.6	5.7	.	.	5.7
88	2853.8	36.0	0.0	2889.8	2933.8	42.6	.	2976.4	60.0	6.6	.	86.6	2.7	15.5	.	2.9
89	608.2	0.0	0.0	608.2	747.5	.	.	747.5	139.3	.	.	139.3	18.6	.	.	18.6
								AVERAGE:	107.6	87.3	52.0	180.5	5.7	11.3	13.1	7.6
								SAMPLE SIZE:	39	29	6	39	39	29	6	39

Table J. (Continued)

Rates for Stratum 3

	ACTUAL CUBIC FEET PER ACRE				EXPECTED CUBIC FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
15	1564.2	0.0	0.0	1564.2	1712.1	.	.	1712.1	147.9	.	.	147.9	8.6	.	.	8.6
16	2226.1	0.0	0.0	2226.1	2377.2	.	.	2377.2	151.1	.	.	151.1	6.4	.	.	6.4
18	2412.3	0.0	0.0	2412.3	2592.6	.	.	2592.6	180.3	.	.	180.3	7.0	.	.	7.0
40	4110.1	160.1	0.0	4270.2	4211.0	175.9	.	4386.9	100.9	15.8	.	116.7	2.4	9.0	.	2.7
41	1200.3	336.1	0.0	1536.4	1164.6	376.3	.	1540.9	-35.7	40.2	.	4.5	-3.1	10.7	.	0.3
42	1031.7	0.0	86.1	1117.8	1053.8	.	96.3	1150.1	22.1	.	10.2	32.3	2.1	.	10.6	2.8
43	1570.9	58.0	0.0	1628.9	1634.5	61.9	.	1696.4	63.6	3.9	.	67.5	3.9	6.3	.	4.0
45	1316.4	0.0	0.0	1316.4	1360.7	.	.	1360.7	44.3	.	.	44.3	3.3	.	.	3.3
48	1612.5	0.0	0.0	1612.5	1612.5	.	.	1612.5	0.0	.	.	0.0	0.0	.	.	0.0
49	2093.2	0.0	0.0	2093.2	2162.0	.	.	2162.0	68.8	.	.	68.8	3.2	.	.	3.2
50	1618.0	0.0	0.0	1618.0	1799.8	.	.	1799.8	181.8	.	.	181.8	10.1	.	.	10.1
51	994.1	0.0	0.0	994.1	934.1	.	.	934.1	-60.0	.	.	-60.0	-6.4	.	.	-6.4
52	897.2	0.0	0.0	897.2	962.5	.	.	962.5	65.3	.	.	65.3	6.8	.	.	6.8
53	1555.2	0.0	0.0	1555.2	1660.4	.	.	1660.4	105.2	.	.	105.2	6.3	.	.	6.3
54	451.5	0.0	0.0	451.5	483.7	.	.	483.7	32.2	.	.	32.2	6.7	.	.	6.7
55	2178.1	0.0	0.0	2178.1	2334.5	.	.	2334.5	156.4	.	.	156.4	6.7	.	.	6.7
56	732.9	0.0	0.0	732.9	745.5	.	.	745.5	12.6	.	.	12.6	1.7	.	.	1.7
57	4297.3	0.0	0.0	4297.3	4428.2	.	.	4428.2	130.9	.	.	130.9	3.0	.	.	3.0
90	3053.9	275.2	0.0	3329.1	3121.7	312.1	.	3433.8	67.8	36.9	.	104.7	2.2	11.8	.	3.0
91	645.5	937.7	0.0	1583.2	664.7	981.6	.	1646.3	19.2	43.9	.	63.1	2.9	4.5	.	3.8
92	1656.9	731.2	0.0	2388.1	1656.9	793.4	.	2450.3	0.0	62.2	.	62.2	0.0	7.8	.	2.5
93	3735.3	833.4	0.0	4568.7	3931.0	894.4	.	4825.4	195.7	61.0	.	256.7	5.0	6.8	.	5.3
94	2043.6	614.5	0.0	2658.1	2135.1	803.2	.	2938.3	91.5	188.7	.	280.2	4.3	23.5	.	9.5
95	2256.4	376.7	0.0	2633.1	2395.0	427.1	.	2822.1	138.6	50.4	.	189.0	5.8	11.8	.	6.7
96	5458.6	1316.0	0.0	6774.6	5912.4	1402.1	.	7314.5	453.8	86.1	.	539.9	7.7	6.1	.	7.4
97	3965.3	110.5	0.0	4075.8	4310.4	121.6	.	4432.0	345.1	11.1	.	356.2	8.0	9.1	.	8.0
98	1200.9	0.0	0.0	1200.9	1264.6	.	.	1264.6	63.7	.	.	63.7	5.0	.	.	5.0
99	1473.4	0.0	0.0	1473.4	1569.9	.	.	1569.9	96.5	.	.	96.5	6.1	.	.	6.1
100	2138.5	1015.2	0.0	3153.7	2256.3	1084.7	.	3341.0	117.8	69.5	.	187.3	5.2	6.4	.	5.6
101	2718.0	423.4	0.0	3141.4	2882.4	492.1	.	3374.5	164.4	68.7	.	233.1	5.7	14.0	.	6.9
102	1967.4	0.0	0.0	1967.4	2021.8	.	.	2021.8	54.4	.	.	54.4	2.7	.	.	2.7
103	2579.2	0.0	0.0	2579.2	2579.2	.	.	2579.2	0.0	.	.	0.0	0.0	.	.	0.0
104	4956.9	0.0	0.0	4956.9	5090.3	.	.	5090.3	133.4	.	.	133.4	2.6	.	.	2.6
105	2449.9	0.0	0.0	2449.9	2568.0	.	.	2568.0	118.1	.	.	118.1	4.6	.	.	4.6
106	2072.4	0.0	0.0	2072.4	2072.3	.	.	2072.3	-0.1	.	.	-0.1	-0.0	.	.	-0.0
107	1532.5	18.0	0.0	1550.5	1567.9	21.9	.	1589.8	35.4	3.9	.	39.3	2.3	17.8	.	2.5
108	2180.6	0.0	0.0	2180.6	2180.6	.	.	2180.6	0.0	.	.	0.0	0.0	.	.	0.0
109	1565.0	0.0	0.0	1565.0	1594.5	.	.	1594.5	29.5	.	.	29.5	1.9	.	.	1.9
								AVERAGE:	91.9	53.0	10.2	111.7	3.7	20.4	10.6	4.1
								SAMPLE SIZE:	38	14	1	38	38	14	1	38
								OVERALL AVERAGE:	99.8	76.1	46.0	146.6	4.7	11.0	12.7	5.9
								SAMPLE SIZE:	77	43	7	77	77	43	7	77

Table K. Growth Loss Rates in Volume (Board Feet) per Acre by Species, Stand, and Stratum. Expected volumes were calculated assuming zero height growth in years of known budworm defoliation.

Rates for Stratum 2

STAND	ACTUAL BOARD FEET PER ACRE				EXPECTED BOARD FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	5048.7	401.6	336.5	5786.8	5585.8	550.9	412.0	6548.7	537.1	149.3	75.5	761.9	9.6	27.1	18.3	11.6
21	6982.1	0.0	517.3	7499.4	7568.0	.	594.3	8162.3	585.9	.	77.0	662.9	7.7	.	13.0	8.1
22	13617.7	1687.5	0.0	15305.2	15036.5	2053.2	.	17089.7	1418.8	365.7	.	1784.5	9.4	17.8	.	10.4
23	17125.0	3241.3	0.0	20366.3	17382.5	3639.8	.	21022.3	257.5	398.5	.	656.0	1.5	10.9	.	3.1
24	31049.3	1141.3	0.0	32190.6	35531.2	1324.2	.	36855.4	4481.9	182.9	.	4664.8	12.6	13.8	.	12.7
25	5018.1	1953.1	0.0	6971.2	5356.7	2282.4	.	7679.1	378.6	329.3	.	707.9	7.0	14.4	.	9.2
26	4995.1	2845.2	0.0	7840.3	5339.4	3380.5	.	8719.9	344.3	535.3	.	879.6	6.4	15.8	.	10.1
27	1970.6	3551.4	0.0	5522.0	2092.3	4469.3	.	6561.6	121.7	917.9	.	1039.6	5.8	20.5	.	15.8
28	10522.5	5005.0	0.0	15527.5	10787.7	5502.5	.	16290.2	265.2	497.5	.	762.7	2.5	9.0	.	4.7
29	1317.8	4282.8	0.0	5600.6	1393.4	4956.0	.	6349.4	75.6	673.2	.	748.8	5.4	13.6	.	11.8
30	14322.3	0.0	0.0	14322.3	15025.8	.	.	15025.8	703.5	.	.	703.5	4.7	.	.	4.7
31	4903.3	64.7	0.0	4968.0	5783.7	104.8	.	5888.5	880.4	40.1	.	920.5	15.2	38.3	.	15.6
32	18742.3	833.6	0.0	19576.1	19580.0	857.6	.	20437.8	837.7	24.0	.	861.7	4.3	2.8	.	4.2
33	1357.8	4815.9	0.0	6173.7	1418.8	5204.7	.	6623.5	61.0	388.8	.	449.8	4.3	7.5	.	6.8
34	1898.3	1791.5	0.0	3689.8	1977.5	1993.5	.	3971.0	79.2	202.0	.	281.2	4.0	10.1	.	7.1
35	4539.2	1825.8	0.0	6365.0	4890.3	2151.0	.	7041.3	351.1	325.2	.	676.3	7.2	15.1	.	9.6
36	1859.6	3769.1	0.0	5628.7	1903.9	4364.7	.	6268.6	44.3	595.6	.	639.9	2.3	13.6	.	10.2
37	14360.2	513.8	753.9	15627.9	15728.2	548.8	834.1	17111.1	1368.0	35.0	80.2	1483.2	8.7	6.4	9.6	8.7
38	3890.2	0.0	0.0	3890.2	3962.8	.	.	3962.8	72.6	.	.	72.6	1.8	.	.	1.8
39	1483.9	0.0	0.0	1483.9	1760.2	.	.	1760.2	276.3	.	.	276.3	15.7	.	.	15.7
70	7752.0	5607.4	999.4	14359.8	8245.5	6431.7	1123.2	15800.4	493.5	824.3	123.8	1441.6	6.0	12.8	11.0	9.1
71	1565.3	0.0	1292.8	2858.1	1619.8	.	1566.4	3186.2	54.5	.	273.6	328.1	3.4	.	17.5	10.3
72	1652.2	4825.3	3752.1	10229.6	1819.3	5341.3	4320.9	11481.5	167.1	516.0	568.8	1251.9	9.2	9.7	13.2	10.9
73	5413.1	6196.9	0.0	11610.0	5996.4	7374.6	.	13371.0	583.3	1177.7	.	1761.0	9.7	16.0	.	13.2
74	12092.3	3612.5	0.0	15704.8	12885.2	4142.9	.	17028.1	792.9	530.4	.	1323.3	6.2	12.8	.	7.8
75	5426.1	1450.4	0.0	6876.5	6004.9	1842.3	.	7847.2	578.8	391.9	.	970.7	9.6	21.3	.	12.4
76	12503.9	1065.0	0.0	13568.9	13309.2	1126.9	.	14436.1	805.3	61.9	.	867.2	6.1	5.5	.	6.0
77	586.6	857.2	0.0	1443.8	625.2	1061.1	.	1686.3	38.6	203.9	.	242.5	6.2	19.2	.	14.4
78	13140.1	339.6	0.0	13479.7	13781.2	505.5	.	14286.7	641.1	165.9	.	807.0	4.7	32.8	.	5.6
79	13231.9	0.0	0.0	13231.9	14607.3	.	.	14607.3	1375.4	.	.	1375.4	9.4	.	.	9.4
80	24494.0	15.1	0.0	24509.1	27033.6	27.3	.	27060.9	2539.6	12.2	.	2551.8	9.4	44.7	.	9.4
81	2824.9	251.8	0.0	3076.7	2928.8	297.5	.	3226.3	103.9	45.7	.	149.6	3.5	15.4	.	4.6
82	7553.3	0.0	0.0	7553.3	8006.1	.	.	8006.1	452.8	.	.	452.8	5.7	.	.	5.7
83	6152.5	0.0	0.0	6152.5	6420.6	.	.	6420.6	268.1	.	.	268.1	4.2	.	.	4.2
84	2323.1	2196.5	0.0	4519.6	2444.1	2478.6	.	4922.7	121.0	282.1	.	403.1	5.0	11.4	.	8.2
85	3439.5	99.8	0.0	3539.3	3648.9	127.2	.	3776.1	209.4	27.4	.	236.8	5.7	21.5	.	6.3
87	6310.7	0.0	0.0	6310.7	6901.4	.	.	6901.4	590.7	.	.	590.7	8.6	.	.	8.6
88	10343.0	0.0	0.0	10343.0	10666.5	.	.	10666.5	323.5	.	.	323.5	3.0	.	.	3.0
89	1496.9	0.0	0.0	1496.9	1974.9	.	.	1974.9	478.0	.	.	478.0	24.2	.	.	24.2
								AVERAGE:	609.2	353.6	199.8	893.8	7.1	16.4	13.8	9.1
								SAMPLE SIZE:	39	28	6	39	39	28	6	39

Table K. (Continued)

Rates for Stratum 3

	ACTUAL BOARD FEET PER ACRE				EXPECTED BOARD FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
STAND	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
15	5758.6	0.0	0.0	5758.6	6364.7	.	.	6364.7	606.1	.	.	606.1	9.5	.	.	9.5
16	8937.2	0.0	0.0	8937.2	9513.3	.	.	9513.3	576.1	.	.	576.1	6.1	.	.	6.1
18	10207.2	0.0	0.0	10207.2	10872.7	.	.	10872.7	665.5	.	.	665.5	6.1	.	.	6.1
40	21927.2	509.2	0.0	22436.4	22703.8	603.1	.	23306.9	776.6	93.9	.	870.5	3.4	15.6	.	3.7
41	2389.3	776.7	0.0	3166.0	2266.8	992.6	.	3259.4	-122.5	215.9	.	93.4	-5.4	21.8	.	2.9
42	4136.8	0.0	201.0	4337.8	4232.8	.	221.4	4454.2	96.0	.	20.4	116.4	2.3	.	9.2	2.6
43	6402.1	263.4	0.0	6665.5	6673.1	286.7	.	6959.8	271.0	23.3	.	294.3	4.1	8.1	.	4.2
45	6123.7	0.0	0.0	6123.7	6318.6	.	.	6318.6	194.9	.	.	194.9	3.1	.	.	3.1
48	8692.0	0.0	0.0	8692.0	8713.7	.	.	8713.7	21.7	.	.	21.7	0.2	.	.	0.2
49	10013.2	0.0	0.0	10013.2	10509.8	.	.	10509.8	496.6	.	.	496.6	4.7	.	.	4.7
50	6248.5	0.0	0.0	6248.5	6724.0	.	.	6724.0	475.5	.	.	475.5	7.1	.	.	7.1
51	2775.5	0.0	0.0	2775.5	2640.0	.	.	2640.0	-135.5	.	.	-135.5	-5.1	.	.	-5.1
52	2160.6	0.0	0.0	2160.6	2357.8	.	.	2357.8	197.2	.	.	197.2	8.4	.	.	8.4
53	7419.8	0.0	0.0	7419.8	8084.7	.	.	8084.7	664.9	.	.	664.9	8.2	.	.	8.2
54	864.9	0.0	0.0	864.9	958.4	.	.	958.4	93.5	.	.	93.5	9.8	.	.	9.8
55	8717.3	0.0	0.0	8717.3	9436.9	.	.	9436.9	719.6	.	.	719.6	7.6	.	.	7.6
56	3380.0	0.0	0.0	3380.0	3439.5	.	.	3439.5	59.5	.	.	59.5	1.7	.	.	1.7
57	22058.2	0.0	0.0	22058.2	22991.3	.	.	22991.3	933.1	.	.	933.1	4.1	.	.	4.1
90	12014.9	841.8	0.0	12856.7	12494.6	972.2	.	13466.8	479.7	130.4	.	610.1	3.8	13.4	.	4.5
91	3278.5	3731.2	0.0	7009.7	3429.3	3952.7	.	7382.0	150.8	221.5	.	372.3	4.4	5.6	.	5.0
92	5780.2	2981.8	0.0	8762.0	5827.9	3344.2	.	9172.1	47.7	362.4	.	410.1	0.8	10.8	.	4.5
93	18055.4	4119.8	0.0	22175.2	19209.6	4419.9	.	23629.5	1154.2	300.1	.	1454.3	6.0	6.8	.	6.2
94	7919.5	1476.9	0.0	9396.4	8489.5	2004.5	.	10494.0	570.0	527.6	.	1097.6	6.7	26.3	.	10.5
95	9699.6	997.5	0.0	10697.1	10440.5	1151.8	.	11592.3	740.9	154.3	.	895.2	7.1	13.4	.	7.7
96	21808.3	6066.0	0.0	27874.3	23898.6	6636.4	.	30535.0	2090.3	570.4	.	2660.7	8.7	8.6	.	8.7
97	16152.3	347.8	0.0	16500.1	17635.6	414.8	.	18050.4	1483.3	67.0	.	1550.3	8.4	16.2	.	8.6
98	3928.5	0.0	0.0	3928.5	4119.3	.	.	4119.3	190.8	.	.	190.8	4.6	.	.	4.6
99	3490.1	0.0	0.0	3490.1	3783.3	.	.	3783.3	293.2	.	.	293.2	7.7	.	.	7.7
100	11521.0	4862.6	0.0	16383.6	12324.4	5304.4	.	17628.8	803.4	441.8	.	1245.2	6.5	8.3	.	7.1
101	7461.0	1064.6	0.0	8525.6	7892.5	1254.6	.	9147.1	431.5	190.0	.	621.5	5.5	15.1	.	6.8
102	6677.0	0.0	0.0	6677.0	6934.5	.	.	6934.5	257.5	.	.	257.5	3.7	.	.	3.7
103	8935.4	0.0	0.0	8935.4	8896.7	.	.	8896.7	-38.7	.	.	-38.7	-0.4	.	.	-0.4
104	18227.5	0.0	0.0	18227.5	18754.4	.	.	18754.4	526.9	.	.	526.9	2.8	.	.	2.8
105	9603.5	0.0	0.0	9603.5	9981.3	.	.	9981.3	377.8	.	.	377.8	3.8	.	.	3.8
106	7359.8	0.0	0.0	7359.8	7383.3	.	.	7383.3	23.5	.	.	23.5	0.3	.	.	0.3
107	5629.6	0.0	0.0	5629.6	5868.5	.	.	5868.5	238.9	.	.	238.9	4.1	.	.	4.1
108	8167.9	0.0	0.0	8167.9	8242.1	.	.	8242.1	74.2	.	.	74.2	0.9	.	.	0.9
109	5954.9	0.0	0.0	5954.9	6114.4	.	.	6114.4	159.5	.	.	159.5	2.6	.	.	2.6
								AVERAGE:	438.0	253.7	20.4	525.4	4.3	13.1	9.2	4.9
								SAMPLE SIZE:	38	13	1	38	38	13	1	38
								OVERALL AVERAGE:	524.7	321.9	174.2	712.0	5.7	15.4	13.1	7.0
								SAMPLE SIZE:	77	41	7	77	77	41	7	77

Table L. Growth Loss Rates in Volume (Board Feet) per Acre by Species, Stand, and Stratum. Expected volumes were calculated assuming no height growth loss due to budworm-caused tree injury.

Rates for Stratum 2

STAND	ACTUAL BOARD FEET PER ACRE				EXPECTED BOARD FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	5048.7	401.6	336.5	5786.8	5542.8	547.7	408.2	6498.7	494.1	146.1	71.7	711.9	8.9	26.7	17.6	11.0
21	6982.1	0.0	517.3	7499.4	7479.6	.	583.5	8063.1	497.5	.	66.2	563.7	6.7	.	11.3	7.0
22	13617.7	1687.5	0.0	15305.2	14837.9	2027.5	.	16865.4	1220.2	340.0	.	1560.2	8.2	16.8	.	9.3
23	17125.0	3241.3	0.0	20366.3	17148.0	3539.6	.	20687.6	23.0	298.3	.	321.3	0.1	8.4	.	1.6
24	31049.3	1141.3	0.0	32190.6	33886.5	1224.9	.	35111.4	2837.2	83.6	.	2920.8	8.4	6.8	.	8.3
25	5018.1	1953.1	0.0	6971.2	5357.5	2257.0	.	7614.5	339.4	303.9	.	643.3	6.3	13.5	.	8.4
26	4995.1	2845.2	0.0	7840.3	5291.6	3328.4	.	8620.0	296.5	483.2	.	779.7	5.6	14.5	.	9.0
27	1970.6	3551.4	0.0	5522.0	2078.2	4392.7	.	6470.9	107.6	841.3	.	948.9	5.2	19.2	.	14.7
28	10522.5	5005.0	0.0	15527.5	10789.8	5445.4	.	16235.2	267.3	440.4	.	707.7	2.5	8.1	.	4.4
29	1317.8	4282.8	0.0	5600.6	1376.0	4902.4	.	6278.4	58.2	619.6	.	677.8	4.2	12.6	.	10.8
30	14322.3	0.0	0.0	14322.3	14941.3	.	.	14941.3	619.0	.	.	619.0	4.1	.	.	4.1
31	4903.3	64.7	0.0	4968.0	5714.8	104.8	.	5819.6	811.5	40.1	.	851.6	14.2	38.3	.	14.6
32	18742.3	833.8	0.0	19576.1	19377.6	856.3	.	20233.9	635.3	22.5	.	657.8	3.3	2.6	.	3.3
33	1357.8	4815.9	0.0	6173.7	1410.5	5168.8	.	6579.3	52.7	352.9	.	405.6	3.7	6.8	.	6.2
34	1898.3	1791.5	0.0	3689.8	1958.9	1969.6	.	3928.5	60.6	178.1	.	238.7	3.1	9.0	.	6.1
35	4539.2	1825.8	0.0	6365.0	4859.0	2130.4	.	6989.4	319.8	304.6	.	624.4	6.6	14.3	.	8.9
36	1859.6	3769.1	0.0	5628.7	1917.2	4301.0	.	6218.2	57.6	531.9	.	589.5	3.0	12.4	.	9.5
37	14360.2	513.8	753.9	15627.9	15582.3	543.1	823.7	16949.1	1222.1	29.3	69.8	1321.2	7.8	5.4	8.5	7.8
38	3890.2	0.0	0.0	3890.2	3946.2	.	.	3946.2	56.0	.	.	56.0	1.4	.	.	1.4
39	1483.9	0.0	0.0	1483.9	1746.7	.	.	1746.7	262.8	.	.	262.8	15.0	.	.	15.0
70	7752.0	5607.4	999.4	14358.8	8083.0	6272.8	1095.0	15450.8	331.0	665.4	95.6	1092.0	4.1	10.6	8.7	7.1
71	1565.3	0.0	1292.8	2858.1	1612.6	.	1557.5	3170.1	47.3	.	264.7	312.0	2.9	.	17.0	9.8
72	1652.2	4825.3	3752.1	10229.6	1788.0	5229.3	4215.3	11232.6	135.8	404.0	463.2	1003.0	7.6	7.7	11.0	8.9
73	5413.1	6196.9	0.0	11610.0	5856.3	7199.2	.	13055.5	443.2	1002.3	.	1445.5	7.6	13.9	.	11.1
74	12092.3	3612.5	0.0	15704.8	12733.0	4075.2	.	16808.2	640.7	462.7	.	1103.4	5.0	11.4	.	6.6
75	5426.1	1450.4	0.0	6876.5	5956.7	1824.4	.	7781.1	530.6	374.0	.	904.6	8.9	20.5	.	11.6
76	12503.9	1065.0	0.0	13568.9	13174.7	1119.1	.	14293.8	670.8	54.1	.	724.9	5.1	4.8	.	5.1
77	586.6	857.2	0.0	1443.8	625.2	1061.1	.	1686.3	38.6	203.9	.	242.5	6.2	19.2	.	14.4
78	13140.1	339.6	0.0	13479.7	13744.0	503.8	.	14247.8	603.9	164.2	.	768.1	4.4	32.6	.	5.4
79	13231.9	0.0	0.0	13231.9	14434.5	.	.	14434.5	1202.6	.	.	1202.6	8.3	.	.	8.3
80	24494.0	15.1	0.0	24509.1	26566.9	27.3	.	26594.2	2072.9	12.2	.	2085.1	7.8	44.7	.	7.8
81	2824.9	251.8	0.0	3076.7	2903.6	293.4	.	3197.0	78.7	41.6	.	120.3	2.7	14.2	.	3.8
82	7553.3	0.0	0.0	7553.3	7962.3	.	.	7962.3	409.0	.	.	409.0	5.1	.	.	5.1
83	6152.5	0.0	0.0	6152.5	6413.6	.	.	6413.6	261.1	.	.	261.1	4.1	.	.	4.1
84	2323.1	2196.5	0.0	4519.6	2408.6	2442.4	.	4851.0	85.5	245.9	.	331.4	3.5	10.1	.	6.8
85	3439.5	99.8	0.0	3539.3	3586.3	126.0	.	3712.3	146.8	26.2	.	173.0	4.1	20.8	.	4.7
87	6310.7	0.0	0.0	6310.7	6878.0	.	.	6878.0	567.3	.	.	567.3	8.2	.	.	8.2
88	10343.0	0.0	0.0	10343.0	10643.8	.	.	10643.8	300.8	.	.	300.8	2.8	.	.	2.8
89	1496.9	0.0	0.0	1496.9	1962.1	.	.	1962.1	465.2	.	.	465.2	23.7	.	.	23.7
								AVERAGE:	494.1	309.7	171.9	742.9	6.2	15.2	12.3	8.1
								SAMPLE SIZE:	39	28	6	39	39	28	6	39

Table L. (Continued)

Rates for Stratum 3

STAND	ACTUAL BOARD FEET PER ACRE DF	GF	SAF	TOTAL	EXPECTED BOARD FEET PER ACRE DF	GF	SAF	TOTAL	LOSS PER ACRE DF	GF	SAF	TOTAL	PERCENT OF EXPECTED DF	GF	SAF	TOTAL
15	5758.6	0.0	0.0	5758.6	6362.6	.	.	6362.6	604.0	.	.	604.0	9.5	.	.	9.5
16	8937.2	0.0	0.0	8937.2	9486.1	.	.	9486.1	548.9	.	.	548.9	5.8	.	.	5.8
18	10207.2	0.0	0.0	10207.2	10846.9	.	.	10846.9	639.7	.	.	639.7	5.9	.	.	5.9
40	21927.2	509.2	0.0	22436.4	22620.8	597.7	.	23218.5	693.6	88.5	.	782.1	3.1	14.8	.	3.4
41	2389.3	776.7	0.0	3166.0	2269.8	987.7	.	3257.5	-119.5	211.0	.	91.5	-5.3	21.4	.	2.8
42	4136.8	0.0	201.0	4337.8	4229.0	.	220.7	4449.7	92.2	.	19.7	111.9	2.2	.	8.9	2.5
43	6402.1	263.4	0.0	6665.5	6651.2	284.4	.	6935.6	249.1	21.0	.	270.1	3.7	7.4	.	3.9
45	6123.7	0.0	0.0	6123.7	6314.3	.	.	6314.3	190.6	.	.	190.6	3.0	.	.	3.0
48	8692.0	0.0	0.0	8692.0	8701.3	.	.	8701.3	9.3	.	.	9.3	0.1	.	.	0.1
49	10013.2	0.0	0.0	10013.2	10364.5	.	.	10364.5	351.3	.	.	351.3	3.4	.	.	3.4
50	6248.5	0.0	0.0	6248.5	6705.2	.	.	6705.2	456.7	.	.	456.7	6.8	.	.	6.8
51	2775.5	0.0	0.0	2775.5	2625.5	.	.	2625.5	-150.0	.	.	-150.0	-5.7	.	.	-5.7
52	2160.6	0.0	0.0	2160.6	2323.9	.	.	2323.9	163.3	.	.	163.3	7.0	.	.	7.0
53	7419.8	0.0	0.0	7419.8	7973.2	.	.	7973.2	553.4	.	.	553.4	6.9	.	.	6.9
54	864.9	0.0	0.0	864.9	955.3	.	.	955.3	90.4	.	.	90.4	9.5	.	.	9.5
55	8717.3	0.0	0.0	8717.3	9346.3	.	.	9346.3	629.0	.	.	629.0	6.7	.	.	6.7
56	3380.0	0.0	0.0	3380.0	3415.8	.	.	3415.8	35.8	.	.	35.8	1.0	.	.	1.0
57	22058.2	0.0	0.0	22058.2	22700.1	.	.	22700.1	641.9	.	.	641.9	2.8	.	.	2.8
90	12014.9	841.8	0.0	12856.7	12375.9	957.4	.	13333.3	361.0	115.6	.	476.6	2.9	12.1	.	3.6
91	3278.5	3731.2	0.0	7009.7	3399.4	3909.7	.	7309.1	120.9	178.5	.	299.4	3.6	4.6	.	4.1
92	5780.2	2981.8	0.0	8762.0	5810.1	3297.0	.	9107.1	29.9	315.2	.	345.1	0.5	9.6	.	3.8
93	18055.4	4119.8	0.0	22175.2	19086.8	4381.5	.	23468.3	1031.4	261.7	.	1293.1	5.4	6.0	.	5.5
94	7919.5	1476.9	0.0	9396.4	8426.0	1972.9	.	10398.9	506.5	496.0	.	1002.5	6.0	25.1	.	9.6
95	9699.6	997.5	0.0	10697.1	10397.4	1146.6	.	11544.0	697.8	149.1	.	846.9	6.7	13.0	.	7.3
96	21808.3	6066.0	0.0	27874.3	23807.6	6602.4	.	30410.0	1999.3	536.4	.	2535.7	8.4	8.1	.	8.3
97	16152.3	347.8	0.0	16500.1	17534.6	411.6	.	17946.2	1382.3	63.8	.	1446.1	7.9	15.5	.	8.1
98	3928.5	0.0	0.0	3928.5	4092.6	.	.	4092.6	164.1	.	.	164.1	4.0	.	.	4.0
99	3490.1	0.0	0.0	3490.1	3770.9	.	.	3770.9	280.8	.	.	280.8	7.4	.	.	7.4
100	11521.0	4862.6	0.0	16383.6	12180.5	5242.6	.	17423.1	659.5	380.0	.	1039.5	5.4	7.2	.	6.0
101	7461.0	1064.6	0.0	8525.6	7881.3	1247.7	.	9129.0	420.3	183.1	.	603.4	5.3	14.7	.	6.6
102	6677.0	0.0	0.0	6677.0	6929.7	.	.	6929.7	252.7	.	.	252.7	3.6	.	.	3.6
103	8935.4	0.0	0.0	8935.4	8900.0	.	.	8900.0	-35.4	.	.	-35.4	-0.4	.	.	-0.4
104	18227.5	0.0	0.0	18227.5	18733.9	.	.	18733.9	506.4	.	.	506.4	2.7	.	.	2.7
105	9603.5	0.0	0.0	9603.5	9965.5	.	.	9965.5	362.0	.	.	362.0	3.6	.	.	3.6
106	7359.8	0.0	0.0	7359.8	7382.8	.	.	7382.8	23.0	.	.	23.0	0.3	.	.	0.3
107	5629.6	0.0	0.0	5629.6	5866.7	.	.	5866.7	237.1	.	.	237.1	4.0	.	.	4.0
108	8167.9	0.0	0.0	8167.9	8242.1	.	.	8242.1	74.2	.	.	74.2	0.9	.	.	0.9
109	5954.9	0.0	0.0	5954.9	6112.1	.	.	6112.1	157.2	.	.	157.2	2.6	.	.	2.6
								AVERAGE:	392.4	230.8	19.7	471.9	3.9	12.3	8.9	4.4
								SAMPLE SIZE:	38	13	1	38	38	13	1	38
								OVERALL AVERAGE:	443.9	284.7	150.1	609.1	5.0	14.3	11.9	6.3
								SAMPLE SIZE:	77	41	7	77	77	41	7	77

Table M. Growth Loss Rates in Volume (Board Feet) per Acre by Species, Stand, and Stratum. Expected volumes were calculated assuming a height growth reduction proportional to the reduction in diameter growth.

Rates for Stratum 2

STAND	ACTUAL BOARD FEET PER ACRE				EXPECTED BOARD FEET PER ACRE				LOSS PER ACRE				PERCENT OF EXPECTED			
	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL	DF	GF	SAF	TOTAL
20	5048.7	401.6	336.5	5786.8	5556.2	540.6	417.7	6514.5	507.5	139.0	81.2	727.7	9.1	25.7	19.4	11.2
21	6982.1	0.0	517.3	7499.4	7605.7	.	601.6	8207.3	623.6	.	84.3	707.9	8.2	.	14.0	8.6
22	13617.7	1687.5	0.0	15305.2	15113.1	2022.9	.	17136.0	1495.4	335.4	.	1830.8	9.9	16.6	.	10.7
23	17125.0	3241.3	0.0	20366.3	17124.5	3558.4	.	20682.9	-0.5	317.1	.	316.6	-0.0	8.9	.	1.5
24	31049.3	1141.3	0.0	32190.6	34317.6	1227.4	.	35545.0	3268.3	86.1	.	3354.4	9.5	7.0	.	9.4
25	5018.1	1953.1	0.0	6971.2	5326.5	2254.6	.	7581.1	308.4	301.5	.	609.9	5.8	13.4	.	8.0
26	4995.1	2845.2	0.0	7840.3	5353.2	3324.6	.	8677.8	358.1	479.4	.	837.5	6.7	14.4	.	9.7
27	1970.6	3551.4	0.0	5522.0	2063.7	4472.7	.	6536.4	93.1	921.3	.	1014.4	4.5	20.6	.	15.5
28	10522.5	5005.0	0.0	15527.5	10774.2	5454.5	.	16228.7	251.7	449.5	.	701.2	2.3	8.2	.	4.3
29	1317.8	4282.8	0.0	5600.6	1369.7	4970.7	.	6340.4	51.9	687.9	.	739.8	3.8	13.8	.	11.7
30	14322.3	0.0	0.0	14322.3	14997.1	.	.	14997.1	674.8	.	.	674.8	4.5	.	.	4.5
31	4903.3	64.7	0.0	4968.0	5743.8	99.6	.	5843.6	840.5	35.1	.	875.6	14.6	35.2	.	15.0
32	18742.3	833.8	0.0	19576.1	19525.5	857.3	.	20382.8	783.2	23.5	.	806.7	4.0	2.7	.	4.0
33	1357.8	4815.9	0.0	6173.7	1405.8	5202.8	.	6608.6	48.0	386.9	.	434.9	3.4	7.4	.	6.6
34	1898.3	1791.5	0.0	3689.8	1955.4	1958.0	.	3913.4	57.1	166.5	.	223.6	2.9	8.5	.	5.7
35	4539.2	1825.8	0.0	6365.0	4907.4	2125.6	.	7033.0	368.2	299.8	.	668.0	7.5	14.1	.	9.5
36	1859.6	3769.1	0.0	5628.7	1913.5	4412.1	.	6325.6	53.9	643.0	.	696.9	2.8	14.6	.	11.0
37	14360.2	513.8	753.9	15627.9	15605.8	544.3	837.1	16987.2	1245.6	30.5	83.2	1359.3	8.0	5.6	9.9	8.0
38	3890.2	0.0	0.0	3890.2	3950.9	.	.	3950.9	60.7	.	.	60.7	1.5	.	.	1.5
39	1483.9	0.0	0.0	1483.9	1778.5	.	.	1778.5	294.6	.	.	294.6	16.6	.	.	16.6
70	7752.0	5607.4	999.4	14358.8	8063.7	6335.4	1120.2	15519.3	311.7	728.0	120.8	1160.5	3.9	11.5	10.8	7.5
71	1565.3	0.0	1292.8	2858.1	1609.4	.	1558.2	3167.6	44.1	.	265.4	309.5	2.7	.	17.0	9.8
72	1652.2	4825.3	3752.1	10229.6	1775.0	5277.4	4335.1	11387.5	122.8	452.1	583.0	1157.9	6.9	8.6	13.4	10.2
73	5413.1	6196.9	0.0	11610.0	5944.2	7339.4	.	13283.6	531.1	1142.5	.	1673.6	8.9	15.6	.	12.6
74	12092.3	3612.5	0.0	15704.8	12902.9	4093.9	.	16996.8	810.6	481.4	.	1292.0	6.3	11.8	.	7.6
75	5426.1	1450.4	0.0	6876.5	6008.9	1812.8	.	7821.7	582.8	362.4	.	945.2	9.7	20.0	.	12.1
76	12503.9	1065.0	0.0	13568.9	13168.1	1120.6	.	14288.7	664.2	55.6	.	719.8	5.0	5.0	.	5.0
77	586.6	857.2	0.0	1443.8	620.2	1055.5	.	1675.7	33.6	198.3	.	231.9	5.4	18.8	.	13.8
78	13140.1	339.6	0.0	13479.7	13826.0	493.7	.	14319.7	685.9	154.1	.	840.0	5.0	31.2	.	5.9
79	13231.9	0.0	0.0	13231.9	14420.6	.	.	14420.6	1188.7	.	.	1188.7	8.2	.	.	8.2
80	24494.0	15.1	0.0	24509.1	26951.3	26.6	.	26977.9	2457.3	11.5	.	2468.8	9.1	43.2	.	9.2
81	2824.9	251.8	0.0	3076.7	2931.3	293.1	.	3224.4	106.4	41.3	.	147.7	3.6	14.1	.	4.6
82	7553.3	0.0	0.0	7553.3	8072.6	.	.	8072.6	519.3	.	.	519.3	6.4	.	.	6.4
83	6152.5	0.0	0.0	6152.5	6350.8	.	.	6350.8	198.3	.	.	198.3	3.1	.	.	3.1
84	2323.1	2196.5	0.0	4519.6	2448.0	2492.0	.	4940.0	124.9	295.5	.	420.4	5.1	11.9	.	8.5
85	3439.5	99.8	0.0	3539.3	3580.7	124.3	.	3705.0	141.2	24.5	.	165.7	3.9	19.7	.	4.5
87	6310.7	0.0	0.0	6310.7	6853.3	.	.	6853.3	542.6	.	.	542.6	7.9	.	.	7.9
88	10343.0	0.0	0.0	10343.0	10577.3	.	.	10577.3	234.3	.	.	234.3	2.2	.	.	2.2
89	1496.9	0.0	0.0	1496.9	2007.6	.	.	2007.6	510.7	.	.	510.7	25.4	.	.	25.4
								AVERAGE:	543.5	330.3	203.0	811.9	6.5	15.3	14.1	8.7
								SAMPLE SIZE:	39	28	6	39	39	28	6	39

Table M. (Continued)

Rates for Stratum 3

STAND	ACTUAL BOARD FEET PER ACRE DF	GF	SAF	TOTAL	EXPECTED BOARD FEET PER ACRE DF	GF	SAF	TOTAL	LOSS PER ACRE DF	GF	SAF	TOTAL	PERCENT OF EXPECTED DF	GF	SAF	TOTAL
15	5758.6	0.0	0.0	5758.6	6425.8	.	.	6425.8	667.2	.	.	667.2	10.4	.	.	10.4
16	8937.2	0.0	0.0	8937.2	9630.0	.	.	9630.0	692.8	.	.	692.8	7.2	.	.	7.2
18	10207.2	0.0	0.0	10207.2	10886.7	.	.	10886.7	679.5	.	.	679.5	6.2	.	.	6.2
40	21927.2	509.2	0.0	22436.4	22557.9	597.4	.	23155.3	630.7	88.2	.	718.9	2.8	14.8	.	3.1
41	2389.3	776.7	0.0	3166.0	2248.8	979.7	.	3228.5	-140.5	203.0	.	62.5	-6.2	20.7	.	1.9
42	4136.8	0.0	201.0	4337.8	4224.1	.	223.6	4447.7	87.3	.	22.6	109.9	2.1	.	10.1	2.5
43	6402.1	263.4	0.0	6665.5	6723.3	285.1	.	7008.4	321.2	21.7	.	342.9	4.8	7.6	.	4.9
45	6123.7	0.0	0.0	6123.7	6380.3	.	.	6380.3	256.6	.	.	256.6	4.0	.	.	4.0
48	8692.0	0.0	0.0	8692.0	8691.9	.	.	8691.9	-0.1	.	.	-0.1	-0.0	.	.	-0.0
49	10013.2	0.0	0.0	10013.2	10397.0	.	.	10397.0	383.8	.	.	383.8	3.7	.	.	3.7
50	6248.5	0.0	0.0	6248.5	6758.9	.	.	6758.9	510.4	.	.	510.4	7.6	.	.	7.6
51	2775.5	0.0	0.0	2775.5	2570.9	.	.	2570.9	-204.6	.	.	-204.6	-8.0	.	.	-8.0
52	2160.6	0.0	0.0	2160.6	2314.4	.	.	2314.4	153.8	.	.	153.8	6.6	.	.	6.6
53	7419.8	0.0	0.0	7419.8	8029.1	.	.	8029.1	609.3	.	.	609.3	7.6	.	.	7.6
54	864.9	0.0	0.0	864.9	974.1	.	.	974.1	109.2	.	.	109.2	11.2	.	.	11.2
55	8717.3	0.0	0.0	8717.3	9360.0	.	.	9360.0	642.7	.	.	642.7	6.9	.	.	6.9
56	3380.0	0.0	0.0	3380.0	3448.0	.	.	3448.0	68.0	.	.	68.0	2.0	.	.	2.0
57	22058.2	0.0	0.0	22058.2	22836.8	.	.	22836.8	778.6	.	.	778.6	3.4	.	.	3.4
90	12014.9	841.8	0.0	12856.7	12320.1	956.9	.	13277.0	305.2	115.1	.	420.3	2.5	12.0	.	3.2
91	3278.5	3731.2	0.0	7009.7	3393.6	3939.2	.	7332.8	115.1	208.0	.	323.1	3.4	5.3	.	4.4
92	5780.2	2981.8	0.0	8762.0	5780.0	3310.9	.	9090.9	-0.2	329.1	.	328.9	-0.0	9.9	.	3.6
93	18055.4	4119.8	0.0	22175.2	19140.4	4408.5	.	23548.9	1085.0	288.7	.	1373.7	5.7	6.5	.	5.8
94	7919.5	1476.9	0.0	9396.4	8361.9	2036.0	.	10397.9	442.4	559.1	.	1001.5	5.3	27.5	.	9.6
95	9699.6	997.5	0.0	10697.1	10368.5	1141.5	.	11510.0	668.9	144.0	.	812.9	6.5	12.6	.	7.1
96	21808.3	6066.0	0.0	27874.3	24097.8	6617.4	.	30715.2	2289.5	551.4	.	2840.9	9.5	8.3	.	9.2
97	16152.3	347.8	0.0	16500.1	17878.8	411.5	.	18290.3	1726.5	63.7	.	1790.2	9.7	15.5	.	9.8
98	3928.5	0.0	0.0	3928.5	4104.6	.	.	4104.6	176.1	.	.	176.1	4.3	.	.	4.3
99	3490.1	0.0	0.0	3490.1	3834.5	.	.	3834.5	344.4	.	.	344.4	9.0	.	.	9.0
100	11521.0	4862.6	0.0	16383.6	12273.9	5271.7	.	17545.6	752.9	409.1	.	1162.0	6.1	7.8	.	6.6
101	7461.0	1064.6	0.0	8525.6	7969.0	1243.6	.	9212.6	508.0	179.0	.	687.0	6.4	14.4	.	7.5
102	6677.0	0.0	0.0	6677.0	6866.9	.	.	6866.9	189.9	.	.	189.9	2.8	.	.	2.8
103	8935.4	0.0	0.0	8935.4	8935.0	.	.	8935.0	-0.4	.	.	-0.4	-0.0	.	.	-0.0
104	18227.5	0.0	0.0	18227.5	18678.0	.	.	18678.0	450.5	.	.	450.5	2.4	.	.	2.4
105	9603.5	0.0	0.0	9603.5	10018.7	.	.	10018.7	415.2	.	.	415.2	4.1	.	.	4.1
106	7359.8	0.0	0.0	7359.8	7359.4	.	.	7359.4	-0.4	.	.	-0.4	-0.0	.	.	-0.0
107	5629.6	0.0	0.0	5629.6	5796.7	.	.	5796.7	167.1	.	.	167.1	2.9	.	.	2.9
108	8167.9	0.0	0.0	8167.9	8167.9	.	.	8167.9	0.0	.	.	0.0	0.0	.	.	0.0
109	5954.9	0.0	0.0	5954.9	6112.4	.	.	6112.4	157.5	.	.	157.5	2.6	.	.	2.6
								AVERAGE:	422.1	243.1	22.6	505.8	4.1	12.5	10.1	4.6
								SAMPLE SIZE:	38	13	1	38	38	13	1	38
								OVERALL AVERAGE:	483.6	302.7	177.2	660.8	5.3	14.4	13.5	6.7
								SAMPLE SIZE:	77	41	7	77	77	41	7	77

Table N. Growth, Mortality, and Total Loss Rates in Basal Area (Square Feet) and Volume (Cubic Feet) per Acre by Stand, Substratum, and Stratum. Three volume losses are presented for growth loss and total loss, these corresponding to expected volumes calculated assuming: (1) zero height growth in years of known budworm defoliation, (2) no height growth loss due to budworm-caused tree injury, and (3) a height growth reduction proportional to the reduction in diameter growth.

Rates for Stratum 2, Single-Storied, Pure Host

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VOL	VOL	BA	VOL	VOL	VOL	BA	VOL	BA	VOL	VOL	VOL
70	140.0	10.9	415.1	302.2	337.2	0.078	2.965	2.158	2.408	6.0	170.5	16.9	585.6	472.7	507.7
71	44.0	2.6	65.3	57.1	61.9	0.058	1.484	1.298	1.407	2.0	32.7	4.6	98.0	89.8	94.6
72	102.0	6.6	245.1	167.0	212.6	0.065	2.403	1.637	2.084	10.0	139.2	16.6	384.3	306.2	351.8
73	104.0	10.4	412.5	309.0	378.3	0.101	3.967	2.972	3.638	24.0	463.5	34.4	876.0	772.5	841.8
74	102.0	7.4	293.4	244.9	284.6	0.072	2.876	2.401	2.790	18.0	585.4	25.4	878.8	830.3	870.0
75	126.0	10.1	362.2	308.3	328.3	0.080	2.875	2.447	2.606	26.0	459.2	36.1	821.4	767.5	787.5
76	117.3	4.3	195.7	145.9	150.2	0.037	1.668	1.244	1.280	5.3	132.9	9.7	328.6	278.8	283.1
77	32.0	2.5	66.1	66.1	68.0	0.079	2.066	2.066	2.125	0.0	0.0	2.5	66.1	66.1	68.0
78	118.2	5.8	182.9	168.4	193.0	0.049	1.548	1.425	1.633	1.8	43.4	7.6	226.3	211.8	236.4
79	106.3	7.0	247.0	205.0	209.9	0.066	2.325	1.929	1.976	1.3	27.1	8.2	274.1	232.1	237.0
AVERAGE	99.2	6.8	248.5	197.4	222.4	0.068	2.418	1.958	2.195	9.4	205.4	16.2	453.9	402.8	427.8

Rates for Stratum 2, Single-Storied, Mixed Host/Nonhost

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VOL	VOL	BA	VOL	VOL	VOL	BA	VOL	BA	VOL	VOL	VOL
80	155.2	11.1	443.4	349.4	423.9	0.072	2.858	2.252	2.732	6.9	190.7	18.0	634.1	540.1	614.6
81	47.2	1.1	43.7	29.6	38.1	0.024	0.926	0.627	0.807	0.8	14.1	1.9	57.8	43.7	52.2
82	52.6	2.4	76.2	65.9	88.5	0.046	1.448	1.252	1.682	0.0	0.0	2.4	76.2	65.9	88.5
83	122.0	3.8	91.4	90.6	73.0	0.031	0.749	0.743	0.598	2.0	55.2	5.8	146.6	145.8	128.2
84	52.0	2.6	101.1	72.9	98.5	0.049	1.944	1.402	1.894	2.0	32.9	4.6	134.0	105.8	131.4
85	56.0	1.9	87.9	48.6	51.7	0.034	1.570	0.868	0.923	2.0	64.7	3.9	152.6	113.3	116.4
87	98.0	4.4	148.2	134.0	136.6	0.044	1.512	1.367	1.394	0.0	0.0	4.4	148.2	134.0	136.6
88	126.0	3.5	115.8	104.2	86.6	0.027	0.919	0.827	0.687	6.0	207.4	9.5	323.2	311.6	294.0
89	36.0	4.8	129.8	119.4	139.3	0.132	3.606	3.317	3.869	0.0	0.0	4.8	129.8	119.4	139.3
AVERAGE	82.8	3.9	137.5	112.7	126.2	0.051	1.726	1.406	1.621	2.2	62.8	6.1	200.3	175.5	189.0

Table N. (Continued)

Rates for Stratum 2, Multi-Storied, Pure Host

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VCL	VOL	BA	VOL	VCL	VOL	BA	VOL	BA	VOL	VOL	VOL
20	92.0	7.9	230.0	197.3	214.6	0.086	2.500	2.145	2.333	0.0	0.0	7.9	230.0	197.3	214.6
21	60.0	4.3	151.9	124.6	161.1	0.072	2.532	2.077	2.685	8.0	273.1	12.3	425.0	397.7	434.2
22	140.0	10.6	359.4	278.9	354.8	0.076	2.567	1.992	2.534	0.0	0.0	10.6	359.4	278.9	354.8
23	124.0	2.7	149.9	76.6	77.6	0.022	1.209	0.618	0.626	2.0	29.7	4.7	179.6	106.3	107.3
24	202.5	13.8	846.6	450.4	531.8	0.068	4.181	2.224	2.626	5.0	89.1	18.8	935.7	539.5	620.9
25	96.4	5.5	177.4	147.0	145.9	0.057	1.841	1.526	1.514	0.0	0.0	5.5	177.4	147.0	145.9
26	96.0	7.0	260.6	208.3	232.3	0.073	2.715	2.170	2.420	2.0	61.1	9.0	321.7	269.4	293.4
27	60.0	6.6	233.5	200.3	220.8	0.109	3.892	3.338	3.680	2.0	60.4	8.6	293.9	260.7	281.2
28	118.0	6.0	215.3	184.6	190.5	0.051	1.825	1.564	1.614	0.0	0.0	6.0	215.3	184.6	190.5
29	81.7	5.9	199.1	166.0	192.6	0.073	2.438	2.032	2.358	5.0	157.7	10.9	356.8	323.7	350.3
AVERAGE	107.1	7.0	282.4	203.4	232.2	0.069	2.570	1.969	2.239	2.4	67.1	9.4	349.5	270.5	299.3

Rates for Stratum 2, Multi-Storied, Mixed Host/Nonhost

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VUL	VOL	VOL	BA	VOL	VOL	VOL	BA	VOL	BA	VOL	VOL	VOL
30	86.0	3.0	110.5	94.3	105.9	0.034	1.285	1.096	1.231	10.0	264.1	13.0	374.6	358.4	370.0
31	72.0	6.8	205.0	165.8	187.2	0.094	2.847	2.303	2.600	0.0	0.0	6.8	205.0	165.8	187.2
32	103.1	3.1	146.4	108.1	135.0	0.030	1.420	1.049	1.310	1.5	57.7	4.7	204.1	165.8	192.7
33	72.2	4.2	144.1	122.6	138.9	0.058	1.995	1.698	1.923	2.2	43.8	6.4	187.9	166.4	182.7
34	50.0	2.3	72.7	54.4	54.4	0.046	1.454	1.088	1.088	2.0	40.1	4.3	112.8	94.5	94.5
35	72.0	4.7	159.8	129.6	148.7	0.065	2.219	1.800	2.065	0.0	0.0	4.7	159.8	129.6	148.7
36	58.0	4.2	142.1	111.8	142.9	0.073	2.450	1.928	2.464	4.0	122.3	8.2	264.4	234.1	265.2
37	164.0	10.8	338.4	286.1	305.1	0.066	2.063	1.745	1.860	2.0	51.3	12.8	389.7	337.4	356.4
38	34.0	0.6	20.6	17.0	17.7	0.017	0.606	0.500	0.521	2.0	59.0	2.6	79.6	76.0	76.7
39	35.4	4.0	117.1	105.4	122.6	0.113	3.309	2.978	3.464	0.0	0.0	4.0	117.1	105.4	122.6
AVERAGE	74.7	4.4	145.7	119.5	135.8	0.060	1.965	1.618	1.853	2.4	63.8	6.7	209.5	183.3	199.7
STRATUM AVERAGE	91.1	5.6	205.2	159.4	180.5	0.062	2.181	1.746	1.986	4.2	100.7	9.7	305.9	260.2	281.3

Table N. (Continued)

Rates for Stratum 3, Single-Storied, Pure Host

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VOL	VOL	BA	VOL	VCL	VOL	BA	VCL	BA	VOL	VOL	VOL
90	131.7	3.9	164.3	110.5	104.7	0.030	1.248	0.839	0.795	5.0	102.9	8.9	267.2	213.4	207.6
91	58.0	1.9	74.9	54.6	63.1	0.034	1.291	0.941	1.088	2.0	64.1	3.9	139.0	118.7	127.2
92	86.0	1.9	88.4	63.8	62.2	0.023	1.028	0.742	0.723	6.0	234.6	7.9	323.0	298.4	296.8
93	140.0	6.8	273.2	235.0	256.7	0.049	1.951	1.678	1.833	2.0	47.5	8.8	320.7	282.5	304.2
94	111.2	9.1	295.9	253.2	280.2	0.082	2.661	2.277	2.520	1.6	30.5	10.7	326.4	283.7	310.7
95	96.3	6.0	204.6	189.0	189.0	0.062	2.125	1.963	1.963	0.7	18.8	6.7	223.4	207.8	207.8
96	220.0	13.4	497.0	462.5	539.9	0.061	2.259	2.102	2.454	28.0	899.4	41.4	1396.4	1361.9	1439.3
97	138.0	8.1	304.5	268.2	356.2	0.059	2.207	1.944	2.581	6.0	184.3	14.1	488.8	452.5	540.5
98	52.0	2.1	72.9	57.3	63.7	0.041	1.402	1.102	1.225	0.0	0.0	2.1	72.9	57.3	63.7
99	71.7	2.6	84.3	71.7	96.5	0.037	1.176	1.000	1.346	0.0	0.0	2.6	84.3	71.7	96.5
AVERAGE	110.5	5.6	206.0	176.6	201.2	0.048	1.735	1.459	1.653	5.1	158.2	10.7	364.2	334.8	359.4

Rates for Stratum 3, Single-Storied, Mixed Host/Nonhost

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VOL	VOL	BA	VOL	VOL	VOL	BA	VOL	BA	VOL	VOL	VOL
100	91.7	4.7	202.1	158.3	187.3	0.051	2.205	1.727	2.043	20.0	516.5	24.7	718.6	674.8	703.8
101	152.7	7.5	198.0	195.6	233.1	0.049	1.296	1.281	1.526	7.3	132.7	14.7	330.7	328.3	365.8
102	87.3	2.4	70.1	69.9	54.4	0.027	0.803	0.801	0.623	0.0	0.0	2.4	70.1	69.9	54.4
103	134.0	-0.5	-16.6	-16.3	0.0	-0.004	-0.124	-0.122	0.000	0.0	0.0	-0.5	-16.6	-16.3	0.0
104	228.0	5.9	144.7	143.1	133.4	0.026	0.635	0.628	0.585	0.0	0.0	5.9	144.7	143.1	133.4
105	100.0	3.5	99.8	98.5	118.1	0.035	0.998	0.985	1.181	0.0	0.0	3.5	99.8	98.5	118.1
106	81.8	0.2	5.8	5.7	-0.1	0.003	0.071	0.070	-0.001	0.0	0.0	0.2	5.8	5.7	-0.1
107	63.3	1.8	50.8	51.2	39.3	0.029	0.802	0.808	0.621	0.0	0.0	1.8	50.8	51.2	39.3
108	90.0	0.6	18.7	18.7	0.0	0.007	0.208	0.208	0.000	0.0	0.0	0.6	18.7	18.7	0.0
109	66.0	1.0	29.8	28.5	29.5	0.016	0.452	0.432	0.447	2.0	53.8	3.0	83.6	82.3	83.3
AVERAGE	109.5	2.7	80.3	75.3	79.5	0.024	0.735	0.682	0.703	2.9	70.3	5.6	150.6	145.6	149.8

Table N. (Continued)

Rates for Stratum 3, Multi-Storied, Pure Host

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VOL	VOL	BA	VOL	VOL	VOL	BA	VOL	BA	VOL	VOL	VOL
40	137.8	4.0	140.9	122.2	116.7	0.029	1.023	0.887	0.847	2.2	75.0	6.2	215.9	197.2	191.7
41	76.0	0.3	12.2	10.1	4.5	0.004	0.161	0.133	0.059	0.0	0.0	0.3	12.2	10.1	4.5
42	46.0	1.1	34.4	30.9	32.3	0.024	0.748	0.672	0.702	2.7	65.4	3.8	99.8	96.3	97.7
43	62.0	1.8	57.0	49.7	67.5	0.029	0.919	0.802	1.089	0.0	0.0	1.8	57.0	49.7	67.5
45	46.7	1.1	32.4	30.8	44.3	0.024	0.694	0.660	0.949	0.0	0.0	1.1	32.4	30.8	44.3
AVERAGE	73.7	1.7	55.4	48.7	53.1	0.022	0.709	0.631	0.729	1.0	28.1	2.6	83.5	76.8	81.1

Rates for Stratum 3, Multi-Storied, Mixed Host/Nonhost

		ABSOLUTE GROWTH LOSS PER ACRE				RELATIVE GROWTH LOSS PER ACRE				MORTALITY		TOTAL LOSS PER ACRE			
STAND	HOST BA	BA	VOL	VOL	VOL	BA	VOL	VOL	VOL	BA	VOL	BA	VOL	VOL	VOL
15	64.0	4.6	123.8	123.9	147.9	0.072	1.934	1.936	2.311	0.0	0.0	4.6	123.8	123.9	147.9
16	80.0	3.6	120.8	113.1	151.1	0.045	1.510	1.414	1.889	0.0	0.0	3.6	120.8	113.1	151.1
18	94.0	5.4	164.5	163.5	180.3	0.058	1.750	1.740	1.918	2.0	33.0	7.4	197.5	196.5	213.3
48	46.0	0.1	14.8	1.7	0.0	0.001	0.322	0.037	0.000	0.0	0.0	0.1	14.8	1.7	0.0
49	70.0	2.0	93.5	61.1	68.8	0.029	1.335	0.873	0.983	1.3	34.0	3.3	127.5	95.1	102.8
50	76.0	6.0	182.0	159.9	181.8	0.079	2.396	2.105	2.393	14.0	439.0	20.0	621.0	598.9	620.8
51	50.0	-1.6	-31.7	-41.0	-60.0	-0.032	-0.634	-0.820	-1.200	0.0	0.0	-1.6	-31.7	-41.0	-60.0
52	44.0	2.3	89.3	66.2	65.3	0.053	2.029	1.504	1.484	2.0	45.7	4.3	135.0	111.9	111.0
53	58.0	3.4	115.5	90.1	105.2	0.058	1.991	1.553	1.814	0.0	0.0	3.4	115.5	90.1	105.2
54	25.3	1.0	27.5	24.1	32.2	0.040	1.086	0.951	1.271	0.0	0.0	1.0	27.5	24.1	32.2
55	85.8	5.0	181.9	144.7	156.4	0.058	2.119	1.686	1.822	11.7	309.3	16.6	491.2	454.0	465.7
56	28.0	0.2	12.0	6.3	12.6	0.009	0.429	0.225	0.450	0.0	0.0	0.2	12.0	6.3	12.6
57	127.2	3.1	167.3	103.3	130.9	0.024	1.315	0.812	1.029	0.8	22.9	3.9	190.2	126.2	153.8
AVERAGE	65.3	2.7	97.0	78.2	90.2	0.038	1.352	1.078	1.243	2.4	68.0	5.1	165.0	146.2	158.2
STRATUM AVERAGE	89.9	3.3	115.8	99.5	111.7	0.035	1.206	1.015	1.141	3.1	87.1	6.4	202.9	186.6	198.8
OVERALL AVERAGE	90.5	4.5	161.1	129.8	146.6	0.049	1.700	1.385	1.569	3.6	94.0	8.1	255.1	223.8	240.6